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NavPers 92232

16

EMENTARY FIRE CONTROL AND SYSTEM MAINTENANCE
(GFCS Mk 51)

TRAINEE'S GUIDE

1955

BUREAU OF NAVAL PERSONNEL

STUDENT'S MANUAL

for

CLASS "A" FIRE CONTROL TECHNICIANS' COURSE

NAME	RATE	CLASS NO.

PREFACE

To: The Future Fire Control Technician

You have been chosen to receive training in the new and challenging field of electricity and electronics in Gun Fire Control and your success in this training mission is of vast importance to the Navy and to yourself.

It is important to the Navy because the Fleet needs men who can do a real job on electrical, electronic, and other phases of Fire Control equipment. It is important to you because successful experience in this kind of work right now may well launch you into a lifetime career.

Your selection for this special training is not due to chance or luck. You are enrolled in a Navy training school of this kind because you have already shown qualities, such as a high standing in mathematics and an excellent ability to learn, which will bring you success in this field. In addition, to help you develop and apply these qualities, you will be given the finest course of instruction which the Navy can provide. The rest is up to you! Your new mission is to master the basic theory and practical application of electricity and electronics, as applied to Gun Fire Control System Mark 5I.

In this mission we wish you success.

F T SCHOOL STAFF

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INTRODUCTION

You are going to have the Trainee's Guide with you continuously throughout this course. Learn how to use it. Don't lose it. There are not enough copies to reissue one to you. This Student's Manual is a guide and reference for study. It also contains valuable tables and job sheets. You will fill out neatly all items left blank, preferably in ink. There will be individual instructions for filling in blanks where needed. The instructor will check your work periodically and you will be graded on the accuracy of your answers and neatness in general. When you go to sea, your manual will go with you as a text and ready reference for further study.

CLASS "A" FIRE CONTROL TECHNICIANS' COURSE

CURRICULUM OUTLINE

The Trainee's Guide consists of--

1. Valuable information for use in this course and as a ready reference aboard ship to help carry out your duties and in preparation for advancement in rate.

2. Study Guides and Job Sheets to be completed by you to help impress important facts in your memory.

3. Ten sections as follows:

Section No.	Section Title	Periods
I	Introduction to Fire Control	13
II	Electricity Fundamentals	30
III	Electrical Circuits, D-C	39
IV	Alternating Current Electricity	60
V	Safety Precautions	4
VI	Electrical Machinery	45
VII	Basic Electronics	57
VIII	Hand Tools	13
IX	Gun Fire Control System Mk 51	40
X	Fire Control Maintenance	29
	Total	330
	Testing	20
	10 Weeks	350

SECTION I

INTRODUCTION TO FIRE CONTROL

Topic No.	Topic Title	Sheet
1.	Fire Control Indoctrination	I-1-1
2.	Fire Control Theory	I-2-1

SECTION I

TOPIC 1

FIRE CONTROL INDOCTRINATION

A. You Have Learned:	References:
1. The scope of this course in the Preface.	
2. Sections to be taken up.	
B. You Are Learning:	
1. Introduction to Fire Control	
a. Why You Are Here.	
b. History of Fire Control.	NavPers 16116-B, pp. 318-325
c. Importance of Fire Control.	
d. Fire Control Technicians.	
e. On-the-Job duties.	NavPers 10163-A pp. 3-5
2. Administrative Organization	
a. Command.	NavPers 10163-A, p. 10
b. C.I.C.	NavPers 10163-A, p. 10
c. Chief Fire Control Officer.	
d. Battery control.	NavPers 10163-A, p. 11
e. Fire Control Division.	
3. Advancement of the FT	
a. Rating structure.	NavPers 10064
b. Practical factors.	NavPers 10064
c. Examination subjects.	NavPers 10064
d. What to study.	NavPers 10052-B
e. How to study.	

WHY YOU ARE HERE

The Fleet is critically in need of trained Fire Control Technicians, because the qualifications are so high. You must have above-average intelligence, including a GCT plus ARI of 115. You are not colorblind because you have to be able to read values of electrical and mechanical components by their different colors. Repair of delicate equipment requires good manual dexterity, coordination, stamina, emotional stability, and no fear of heights. Great pride will be yours in keeping your equipment in 4.0 condition, even though it may mean that you will have to stay aboard once in a while during liberty to eliminate casualties. You will work twice around the clock, and over, occasionally, to remedy a stubborn casualty. Be a conscientious FT and your prestige among your shipmates will be boundless because they know their life depends on your aim.

HISTORY OF FIRE CONTROL

Fire Control is the technique of firing guns, torpedoes, rockets, depth charges, and other weapons at a selected target. This target may be the enemy who is firing at you. Early guns were fired by aligning the top of the breech and the top of the muzzle with the point of aim, causing the gun to be elevated by the amount of the taper of the gun barrel from breech to muzzle. One early device for correcting for the roll of the ship was a round shot suspended from a spar. The gunner watched this improvised pendulum swing with the roll of the ship and just before it was parallel to the mast, he applied his slow match to the touch hole of the piece. Another practice depending upon the roll of the ship, was that of firing at the crest of the roll to increase the range.

Fixed gun sights were introduced early in the 19th century. Improvements in guns and powder increased the range. Drift caused by rifling in the bore necessitated adjusting the rear sight laterally, and for the increase in range, the rear sight was adjusted vertically to offset the LOS from the bore of the gun.

Gunsight telescopes were developed near the end of the 19th century. The LOS could be offset from the axis of the bore of the gun to correct for range, drift, and relative motion of gun and target. An improvement in operation was effected by installing two sights and dividing the responsibility of keeping on target between the pointer in elevation, and the trainer in train.

At first range was estimated. This became inaccurate as gun accuracy increased and in 1898 a mechanical angle-measuring instrument called a stadimeter was adapted. This led to the development of the coincidence rangefinder which was accurate in clear daylight on surface targets. The stereoscopic rangefinder was designed for use when fast-moving aircraft became active in naval warfare. Telescopes and rangefinders are optical instruments, so, at night and during low visibility, they are useless. Radar has been developed recently. In World War II, our superiority in many naval battles was due almost entirely to our possession of radar. Our latest fire control radars have pinpoint accuracy in any type of weather.

At the start of the 20th century, corrections for relative motion of ship and target were computed on paper. This was too slow and errors were large, even for slow-moving surface targets. This brought about graphic plotting for surface targets. Graphic plotting of a series of ranges and bearings was set down on paper, from which it was possible to determine the approximate course and speed of the target. Later, a mechanical rangekeeper was designed to compute range rate and bearing rate, and to generate present range. Alterations were made to the basic rangekeeper to adjust for wind, gun ballistics, and initial projectile velocity. For air targets, elevation was introduced.

During World War II the Navy developed the compact Lead Computing Sight to calculate gun orders for short-range fast-moving targets. You will study Gun Sight Mk 14 later in this course.

One of the latest fire control instruments is the electronic computer, which solves the fire control problem instantaneously and with exact precision. This is taken up in more advanced schools.

Corrections to deck motion, caused by roll and pitch, appeared during World War I. Instruments correcting deck motion employed the gyroscope, which is very similar to a toy top. The gyroscope is mounted so that as it spins, it remains vertical to the earth's surface at all times, no matter how much the ship rolls and pitches.

Communications are very important to Fire Control in giving firing orders, making reports, carrying out safety precautions, etc. The first method of communication was to shout. This gave way to talking through a rubber hose, then a metal voice tube, which is still used as an auxiliary means of communication.

Externally powered telephones were brought into use so that one control station could communicate with many stations at one time. These telephones needed an external source of power, either ship's power, or batteries. In case the ship lost its power or the batteries were dead, there was no communication and, therefore, no control was exercised over the guns. The adoption of sound-powered telephones, where power is generated by the voice, made communication between guns and control stations independent of any other source of power.

Control of the guns started with the old type of pointer fire where each individual gun worked out its own sight settings and fired the gun at any time between the commence fire and cease fire orders. Later it became evident that a control officer from an elevated station could observe the fall of shot and estimate corrections known as "spots." It soon became evident that with all guns firing individually it was impossible to spot with any accuracy. Buzzers were then used as a signal for all guns to fire at once, but still the guns fired at various times during the signal. The next step was the installation of a master firing key to fire all guns at once. This master firing key was improved on and became known as a director.

The fire control systems of today are very flexible. Gunfire is almost independent of ship maneuvers and is not, as in the past, limited by tactics. By providing duplicate control and computing stations, batteries can be divided to cover several targets at once, or all guns may be directed at the same target. Furthermore, the destruction of any one station does not make it impossible for the battery to continue its fire.

IMPORTANCE OF FIRE CONTROL

Any ship of the line is just a maneuverable gun platform. Its purpose is to get the guns into a firing position. In other words, make contact with the enemy at the most advantageous time and place and on a course that will allow a maximum number of guns to fire.

Every piece of fire control equipment is designed to point the battery in the correct direction so that the projectile will strike the target. If the fire control system is broken down or inaccurate, all purpose for a Navy is defeated.

FIRE CONTROL TECHNICIAN

The Fire Control Technician has many and varied special duties. As an "F.T. striker" you will advance from the apprentice stage to the skilled technician. You can then advance to Warrant Officer or Limited Duty Officer and remain in your line or work. You will be required to master the use of hand tools, many special tools designed for use on a specific type of instrument, and electrical and mechanical instruments used in maintenance and repair of all Fire Control gear. Minor maintenance of optical Fire Control equipment, overhaul of hydraulic power drives, and major repair of all Fire Control gear, including Fire Control radar, are the responsibilities of the FT. You can't be a "slop worker." It takes an "artist" in this field of endeavor to keep gear in 4.0 condition.

ON-THE-JOB DUTIES

You will be assigned to a ship having, as close as possible, the equipment you have been trained for here in school. Your duties will be twofold; you'll have both military and specialty duties.

Your military duties come first, and consist of standing watches at sea and in port, of guard duty, Shore Patrol, landing party exercises, and many other similar jobs. You'll have to know standard ship organization, which you will get in this course. Then, too, you will learn what to do during emergency drills for fire, man overboard, repel boarders, etc.

Your special duties will be maintaining and operating fire control equipment. You must be able to operate the fire control equipment to which assigned. When you master this, then learn to operate the other fire control systems on the ship. Your battle station will be on the equipment assigned to you. Your life and the lives of others depends on your being able to cope with all modes of operation.

You must maintain, with proper instruction and supervision by senior petty officers, all fire control gear to which you are assigned. All gear must be kept perfectly clean. Checks, tests, and operational adjustments will be a major part of your specialty duties. You will also assist your seniors in major repair and overhaul. You will be surprised how quickly you "get the feel" of your tools.

When you find out what to do on the job, why it has to be done, and how to do it, you are on your way to being a proficient F. T.

A running history has to be kept up to date on your equipment every day. This is called a "Rough Log" and contains entries on tests, checks, drills, and maintenance. When you are assigned to a system, read the rough log. It contains much valuable information.

ADMINISTRATIVE ORGANIZATION

Command

The Captain is responsible for the supervision of ship's course and speed, the use of armament, the preservation of watertight integrity, rectification of casualties to personnel and material, and the receipt and dissemination of all communications.

Combat Information Center

The senior officer is the Executive Officer or Operations Officer. He collects, evaluates, and distributes combat information within the ship and to other ships in the area. C.I.C., as it is called, uses radio, sonar, and radar as its eyes and ears, evaluates this information, and relays it to the proper station.

Chief Fire Control Officer

The Gunnery Officer is the Chief Fire Control Officer, and mans his battle station in the fire control tower on large ships. On destroyers or smaller ships he will be stationed in C.I.C. on the bridge, or some other convenient location where he can exercise indirect control over the main, AA, torpedo, rocket, or any other type battery his particular ship may have. On large ships he usually has direct control of the main battery and controls the other batteries through his subordinate officers. This set-up is standard for one type of ship, but will change for different types of ships. As more advanced weapons are developed, the gunnery organization has to change to exercise full control at all times.

Battery Control

In each director there is a group control officer under supervision of the Gunnery Officer. Each group control officer has direct control over the guns assigned to him, and has communication with plotting rooms and fire control radar.

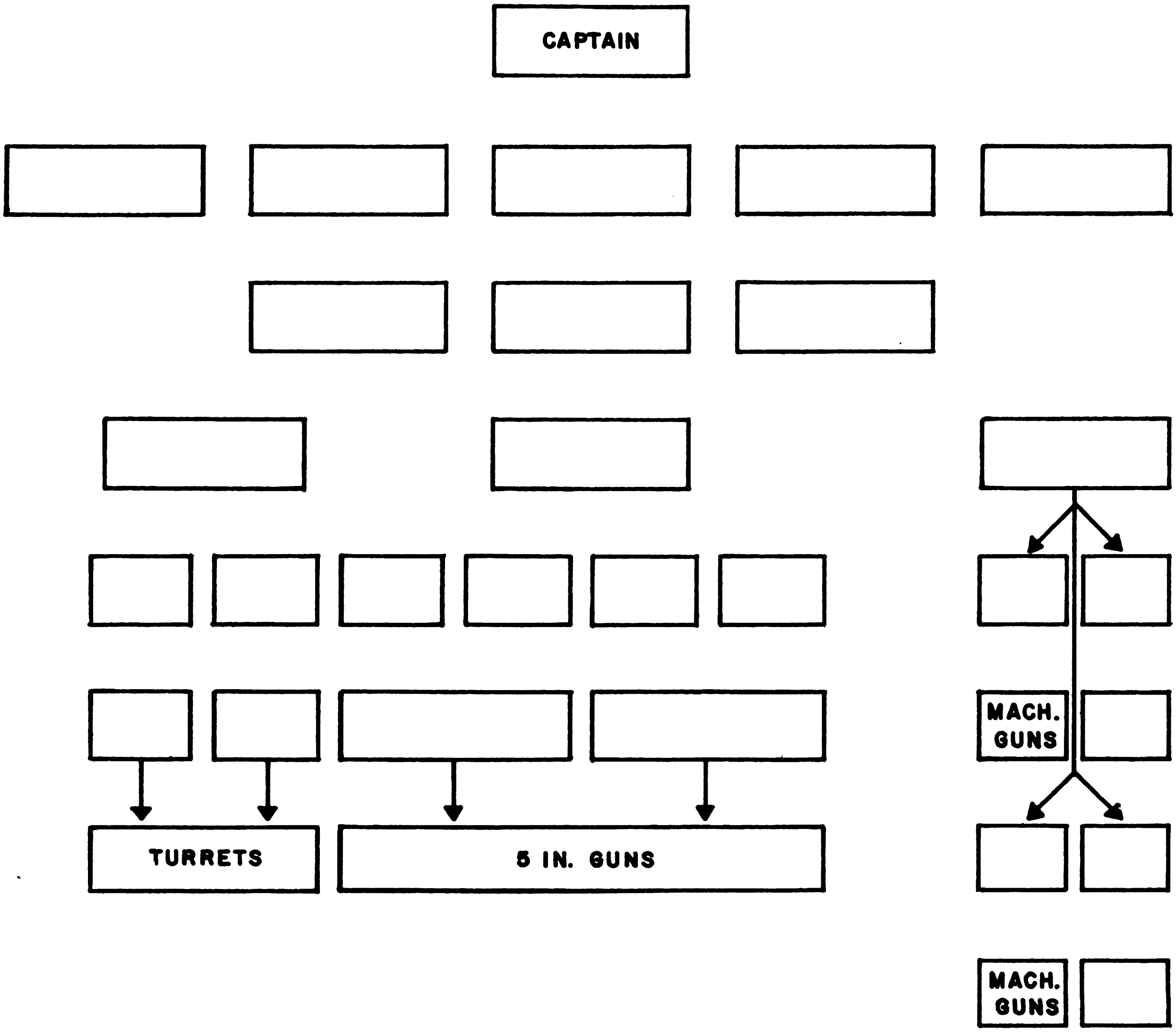
FIRE CONTROL DIVISION

The Fire Control Division is headed by the Fire Control Officer and is responsible to the Gunnery Officer for the operation and maintenance of all fire control gear. The organization of personnel within the division will vary with each type of ship.

JOB SHEET NO. 1 Battleship Fire Control Organization

Instructions: Complete the block diagram of the Fire Control organization, following the chain of command from top to bottom.

Reference: NavPers 10163-A, sheet 9.



ADVANCEMENT OF THE FT

Rating Structure

The following is the path to follow for the advancement of the FT in his own particular specialty.

1.	Seaman Recruit	SR
2.	Seaman Apprentice	SA
3.	Seaman	SN
4.	Fire Control Technician Third Class	FT3
5.	Fire Control Technician Second Class	FT2
6.	Fire Control Technician First Class	FT1
7.	Chief Fire Control Technician	FTC
8.	Gunner	GUN
9.	Chief Gunner	CH. GUN
10.	Limited Duty Officer	ENS TO CDR

JOB SHEET NO. 2

Instructions: Read NavPers 10064, Sheets 14-22, and fill in the following incomplete statements.

1. Identify electrical and mechanical symbols used in ____________________ of fire control equipment, excluding ____________________.

2. Use RMA color codes for ____________ and resistors.

3. Conduct shipboard tests of _______ _________ ________________.

4. Make operator's adjustments and checks to _________ _________ ___________.

5. Keep rough _________.

6. Precautions to be observed in __________________ fire control equipment.

7. Purposes and types of entries made in __________ ____________________.

8. Identify electronic symbols used in ____________ __________________ of fire control equipment.

9. Trace circuits through fire control __________ _________________.

10. Make ___________ __________________ and keep ordnance histories.

11. Given course and speed of own ship, ___________ __________, and ________________ ________________, solve analytically for range rate and deflection rate.

12. Characteristics and use of __________________ and methods of setting to electrical ________________.

13. Conduct battery alignment tests and _________________ _________________.

14. Test, remove, and adjust mechanical parts of fire control and __________________ _____________________ equipment.

15. Repair mechanical parts of Fire Control and torpedo control equipment, excluding _____________________ and ______________ _________________ work.

FIRE CONTROL TECHNICIANS (FT)

Rating Code No. 0800

GENERAL SERVICE RATING FOR FT3

Scope

Fire Control Technicians maintain and repair fire control systems, including fire control radars and target designation equipment; make detailed mechanical, electrical, and electronic casualty analyses; test, operate, clean, lubricate, inspect, adjust, and calibrate fire control units; remove, repair, replace, and install, or reassemble fire control components and systems; make transmission, computing, and rate test on fire control systems; boresight guns and aline guns and fire control systems.

NAVY ENLISTED CLASSIFICATION CODES

For specific Navy enlisted classification codes included within this rating, see Manual of Navy Classifications, NavPers 15105 (revised), codes FT-1100 to FT-1099.

QUALIFICATIONS FOR ADVANCEMENT TO FT3

100 PRACTICAL FACTORS

101 Operational

1. Demonstrate method of resuscitating, or reviving, a man unconscious from electrical shock, and treatment for electrical burns.

2. Read dials and set operating controls to predetermined values on fire control equipment.

3. Demonstrate, on fire control equipment to which assigned, operating procedures and techniques as required to perform operator's adjustments.

4. Demonstrate, on target designation equipment of own ship, operating procedures and techniques required to perform operator's adjustments.

102 Maintenance and/or Repair

1. Identify electrical and mechanical symbols used in schematic diagrams of fire control equipment, excluding radar.

2. Identify capacitors and resistors by RMA color codes.

3. Lubricate fire control equipment in accordance with lubrication charts.

4. Make tests of electrical fire control circuits for continuity, grounds, and short circuits, and make repairs as necessary.

5. Inspect and clean commutator and slipring assemblies and replace brushes.

6. Make prescribed electronic tests of servo and computing circuits, using multimeters, tube testers, and cathode ray oscilloscopes, and report results.

7. Make operator's adjustments and checks to fire control radars.

8. Conduct shipboard tests of gyro-controlled computing mechanisms, such as lead computing sights and other restrained gyros used in computing angular rate lead angles.

103 Administrative and/or Clerical

1. Keep rough logs of periodic tests and maintenance.

200 EXAMINATION SUBJECTS

201 Operational

1. Interpret and interpolate a dial setting into minutes, degrees, yards, or mils.

202 Maintenance and/or Repair

1. Types of information shown and meaning of electrical and mechanical symbols used in schematic diagrams of fire control equipment, excluding radar and fire control quantities.

2. RMA color coding systems for capacitors and resistors.

3. Precautions to be observed in lubricating Fire Control equipment.

4. Methods and equipment used in electrical tests for continuity, grounds, and short circuits.

5. Methods of testing resistors, potentiometers, coils, transformers, capacitors, and vacuum tubes and the application of each in voltage amplifier, phase inverter, power supply, oscillator, power supply circuits, and coupling circuits.

6. Function of each of the elements in gas-filled, electron, and cathode ray tubes.

7. Calculate current, voltage, phase angle, impedence, and resistance in series and parallel circuits containing a combination of not more than four elements.

8. Purposes of the following fire control radar operator's adjustments and checks: intensity, sweep, focus, centering, receiver gain, receiver tuning, video gain, modulator frequency, range slew, range and train and elevation zero checks.

9. Properties of free and restrained gyroscopes and purpose of damping.

10. Purpose and interpretation of shipboard tests of gyro-controlled computing mechanisms, such as lead computing sights and other restrained gyros used in computing angular rate lead angles.

203 Administrative and/or Clerical

1. Types, purpose of, and entries made in rough logs.

What to study

Mandatory training courses for FT 3

1. Fire Controlman 3, Vol. 1.	NavPers 10163-A
2. Fire Controlman 3, Vol. 2.	NavPers 10164-A
3. Electricity for FC and FT, Vol. 1.	NavPers 10170
4. Electricity for FC and FT, Vol. 2.	NavPers 10171
5. General Training Course for Petty Officers.	NavPers 10055

Helpful Publications and Training Courses

1. Electricity.	NavPers 10622-B
2. Fire Control Fundamentals.	NavPers 91901

3.	Advanced Mathematics (Chapter 1 and 2).	NavPers 10071
4.	Bluejackets Manual (1950).	None
5.	Survival in the Water.	NavPers 10080
6.	Chemical and Biological Warfare Defense (Chapter 2-5, 11).	NavPers 10098
7.	U.S. Naval Security Manual for Classified Matter.	OpNav 5510.1A
8.	Personal Affairs of Naval Personnel (Chapters 1, 3, 7, and 8).	NavPers 15014 (1953)
9.	U.S. Navy Regulations, 1948 (Chapter 12).	None
10.	Basic Fire Control Mechanisms.	OP 1140
11.	Radar System Fundamentals.	NavShips 900,017
12.	GFCS Mk 56 (Preliminary).	OP 1600
13.	Use of Blueprints.	NavPers 10621
14.	Use of Tools.	NavPers 10623
15.	Basic Machines.	NavPers 10624

16. In addition, you will study the publications which are applicable to the equipment to which you are assigned, such as OP 821 A for Power Drive Mk 4, and OP 4429 for Gun Sight Mk 14.
17. There are also Fleet and Type publications which pertain to your fleet or specific type of ship.
18. Ordnance Data (O.D.), Ordnance Technical Instructions (O.T.I.), Field Changes, Ordnance Alternations, Ordalts, etc.
19. This list was made up to help you select a reference for study. Don't forget it when you go to sea.

JOB SHEET NO. 3

How to study

Instructions: Fill in blanks with proper information obtained from lectures.

Proper study conditions

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Proper study time

1. ______________________________
2. ______________________________
3. ______________________________

Regular procedure

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Study places at your present duty station

1.______________________________

2.______________________________

Study places at sea

1.______________________________

2.______________________________

JOB SHEET NO. 4

Introductory Tour of School Organization

Instructions: Fill in Rank and Name.

Commanding Officer ________________________

Executive Officer ________________________

Officer-in-Charge ________________________

Ass't Officer-in-Charge ________________________

Unit No. 1 ________________________

Unit No. 2 ________________________

Unit No. 3 ________________________

USE THE FOLLOWING SPACE FOR USEFUL NOTES

JOB SHEET NO. 5

Introductory Tour of Ordnance Equipment

Instructions: Fill in building number, room number, type, mark and mod, and manufacturer of equipment visited.

1. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

2. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

3. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

4. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

5. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

6. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

7. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

8. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

9. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

0. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

1. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

2. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

3. BLDG.____________ ROOM________ TYPE____________

MK.________ MOD.________ MFGR.________________

Introductory Tour of Ordnance Equipment

14. BLDG.________________ ROOM ________ TYPE ________________

MK.________ MOD.________ MFGR.____________________

15. BLDG.________________ ROOM ________ TYPE ________________

MK.________ MOD.________ MFGR.____________________

16. BLDG.________________ ROOM ________ TYPE ________________

MK.________ MOD.________ MFGR.____________________

17. BLDG.________________ ROOM ________ TYPE ________________

MK.________ MOD.________ MFGR.____________________

SECTION I

TOPIC 2

FIRE CONTROL THEORY

A. You have learned:	References:
1. The scope of this course.	
2. Sections to be taken up.	
3. Fire control indoctrination.	
B. You are learning:	
1. Laying the gun.	NavPers 10163-A, pages 23-24
2. The projectile.	NavPers 16116-B, pages 20-33
3. Interior and exterior ballistics.	NavPers 10163-A, pages 201-216
4. General description of the fire control problem.	NavPers 10163-A, pages 29-32
5. Solving the fire control problem.	NavPers 10163-A, pages 29-32
a. Own ship and target motion	
b. Predictions	
c. Gun orders	
d. Effects of wind	
e. Generated rates	
6. Basic mechanical units.	NavPers 10163-A, pages 37-81
7. Fire Control symbols and nomenclature.	NavPers 10163-A, pages 441-444
8. Accuracy and precision of equipment.	NavPers 10163-A, pages 32-33
9. Composition of a fire control system.	NavPers 10163-A, page 28

LAYING THE GUN

Laying the gun is the process of training and elevating it to a position where it will score hits. The target is continuously maneuvering, own ship is maneuvering, and the ship is rolling and pitching. Therefore, the gun angles have to be corrected for target motion, own ship's motion, and at the same time, for roll and pitch of own ship. As the target increases or decreases range, gun elevation will change. As the target moves to the right or left, the gun has to lead the target. The motion of own ship toward the target would cause the projectile to fall beyond the target, so the gun is depressed. The motion of own ship away from the target would cause the projectile to fall short, so the gun is elevated. The motion of own ship to the right or left would cause the projectile to fall in that direction, so the gun is moved in the opposite direction. Roll and pitch cause errors in train and elevation. A wind will blow the projectile out of its normal path, gravity will pull down on the projectile, and drift moves the projectile to the right. Also, other errors have to be corrected for.

The effects of drift and wind are not corrected for in Gun Sight Mk 14.

THE PROJECTILE

The propelling charge is the powder that drives the projectile out of the gun and through the air. In bag ammunition, the propelling charge is a number of silk bags of powder, the number of bags depending on the size of the gun. Some 8-inch, and all larger guns, use bag ammunition. The 16"/50 gun, the largest gun in use today, uses six bags of powder. In semifixed ammunition, the powder is in a case separate from the projectile. This type ammunition is used in some 5-inch, 6-inch, and 8-inch guns. Fixed ammunition is manufactured in one unit, such as a round of rifle ammunition, and is usually used in 3-inch guns and smaller, such as the 40-mm.

Projectile markings are painted on the projectile in different colors and designs, which determines their specific use. They are classified in three ways: (1) penetrating projectiles, which pierce armor and then explode; (2) fragmenting projectiles, which inflict damage by blast effect and by breaking up into small high-velocity fragments; and (3) special-purpose projectiles, which are designed to illuminate targets at night, cause smoke screen or incendiary effect, scatter metal foil strips (window) high in the air to confuse enemy radars, and several types of projectiles used for target practice.

Most 40-mm ammunition is fired at fast-moving targets such as attacking aircraft and small high-speed boats, such as P.T. boats.

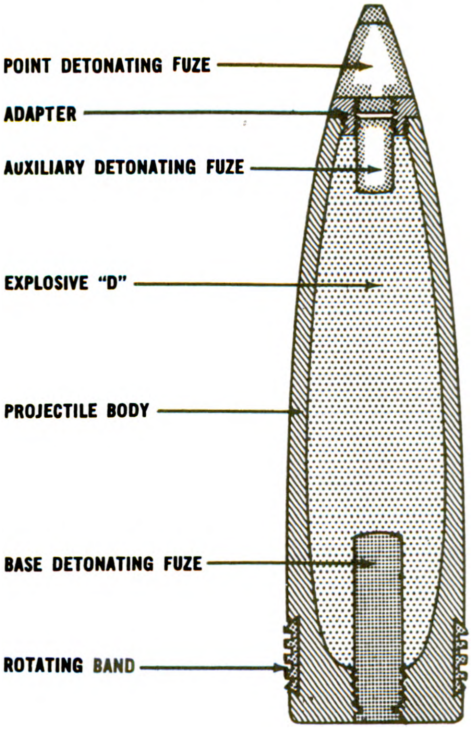
A projectile fuze is a mechanical, electrical, electronic, or magnetic (or combination thereof) device which will detonate or ignite a charge in a projectile at the time and under the circumstances desired. The impact fuze explodes on contact with the target. A time fuze employs a clockwork mechanism used to obtain timed air bursts. The radio proximity or VT fuze is a self-contained, radio-controlled fuze capable of transmitting pulses of radio energy, and of receiving a portion of these pulses which may be reflected by a target. The fuze fires when the returning signal is of sufficient strength, due to proximity of the target.

40-mm fuzes are impact fuzes and burst on contact with the target.

JOB SHEET NO. 6

Parts of the projectile

Instructions: Fill in the names of the different parts of the projectile. Reference: NavPers 16116-B, p. 30.



1. What is the purpose of the rotating band? ______________________________

____

2. What is the purpose of the explosive charge? ______________________________

____

BALLISTICS

Interior ballistics is a study of what happens in the bore of the gun from the time the gun is fired, till the projectile leaves the muzzle. The powder, of which there are many different types, is the propellant for the projectile. Two types of powder used are: smokeless, for day firing, and flashless, for night firing. These different types of powder burn at different rates and therefore affect I.V. (initial velocity), which is the speed, in feet per second, the projectile is traveling as it leaves the bore of the gun. Powder temperature affects burning time and therefore affects I.V.

Erosion is the wearing away of the bore as each round is fired. This causes a decrease in I.V. (initial velocity) because gases escape around the projectile as the bore wears. The size, shape, and weight of the projectile enters into the computations of I.V. before firing starts.

Exterior ballistics is a study of what happens to the projectile after it leaves the gun. This starts with I.V. Air resistance slows the projectile and as it gains altitude, the air density decreases. This decreases the air resistance. The rifling in the bore of the gun causes the projectile to spin clockwise, looking at its base. As the projectile spins, its axis of spin rotates to the right and the trajectory curves to the right. This horizontal deflection of the projectile during flight due to the combined actions of gravity, gyroscopic action, and air resistance is called drift.

Drift is not appreciable at short ranges, but increases rapidly as the range becomes greater. Since projectiles always drift to the right, the gun must be aimed to the left of the target by an amount depending on the range. For greater ranges, drift increases.

The effect of gravity on a projectile's course of flight is always constant in a downward direction; therefore, it is a simple matter to elevate the gun to correct for this error.

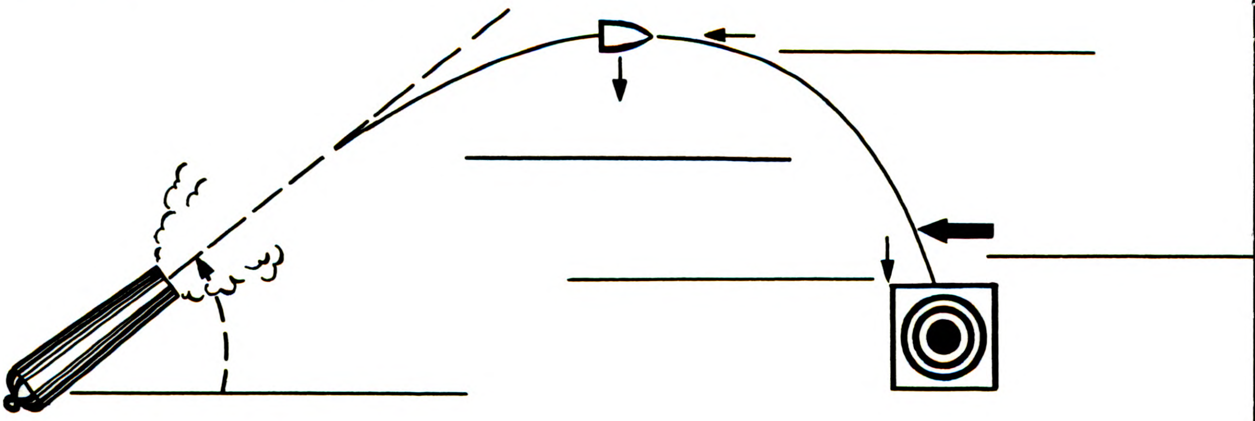
Ballistic corrections other than for the effect of gravity are so small at short ranges they are not corrected for in Gun Sight Mark 14.

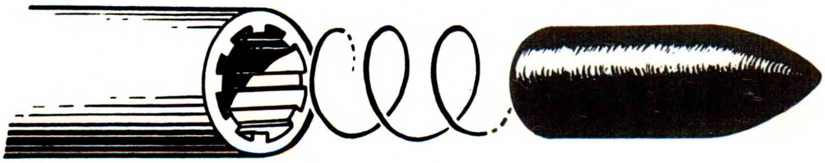
The type of ammunition, I.V., erosion, air resistance, and the effect of gravity on th projectile are taken into consideration during manufacture of the gun sight.

JOB SHEET NO. 7

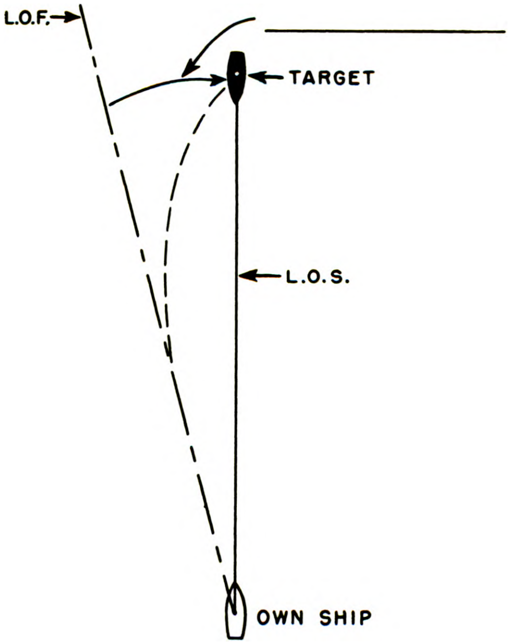
Exterior Ballistics

Instructions: Fill in the following blanks.





THE PROJECTILE ROTATES______________.



GENERAL DESCRIPTION OF THE FIRE CONTROL PROBLEM

Relative motion takes into consideration the effects of movement of the target and own ship in the Fire Control problem. Relative motion is corrected by the director operator as he tracks the target.

Ballistic predictions are corrections to the future position of target for forces acting on the projectile during the time of flight. The only ballistic correction that enters into the Fire Control problem as solved by Gun Sight Mark 14 is made for the effect of gravity on the projectile.

Gun orders are quantities transmitted to the gun so the projectile will hit the target, such as gun train order, gun elevation order, and fuze order. Fuze order is not transmitted to 40-mm guns because they employ point detonating fuzes. As a safety measure, they burst at 4,000-yard range.

Wind also affects the projectile in flight and is broken down into two parts. True wind is the speed and direction of the wind from true north; apparent wind is the resultant of the motion of the true wind and the reversed motion of own ship. As mentioned before, wind is not corrected for in Gun Sight Mk 14, because of its short range.

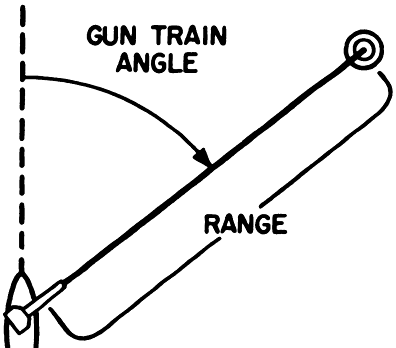
Train, elevation, and range must be constantly generated to correct for constant changes in own ship and target motion. In Gun Fire Control System Mk 51, train and elevation are generated by the director operator tracking the target, and range is set into the gun sight manually by the range setter.

SOLVING THE FIRE CONTROL PROBLEM

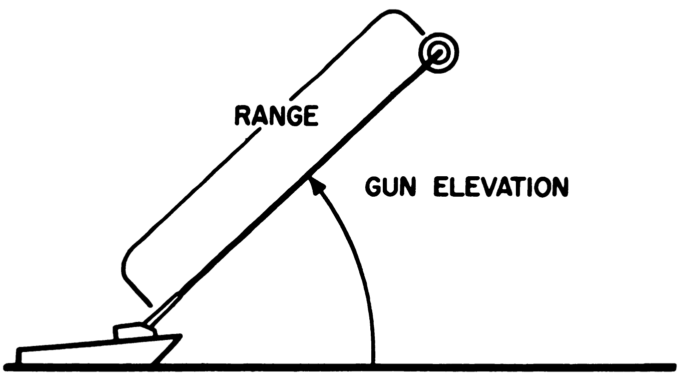
The fire control problem as solved by Gun Fire Control System Mk 51 is primarily the same as for any gun fire control system. The way the GFCS Mk 51 solves this problem is slightly different from that of most systems. The fire control problem in general will be compared directly to the problem as solved by the GFCS Mk 51.

Increased aircraft speeds in World War II made necessary the development of fire control systems which could greatly reduce the time of solution of the problem of hitting aircraft. This step was vitally necessary for the control of machine guns, for which solution time is limited by the relatively short effective range of the guns. The greatest danger to the ship was from incoming planes at close ranges, so many of the factors computed by long-range fire control systems could safely be ignored. The lead-computing or relative-rate systems differ from many other systems in that they measure rate of change of bearing and elevation directly as angular quantities and measure these quantities simply by tracking the target.

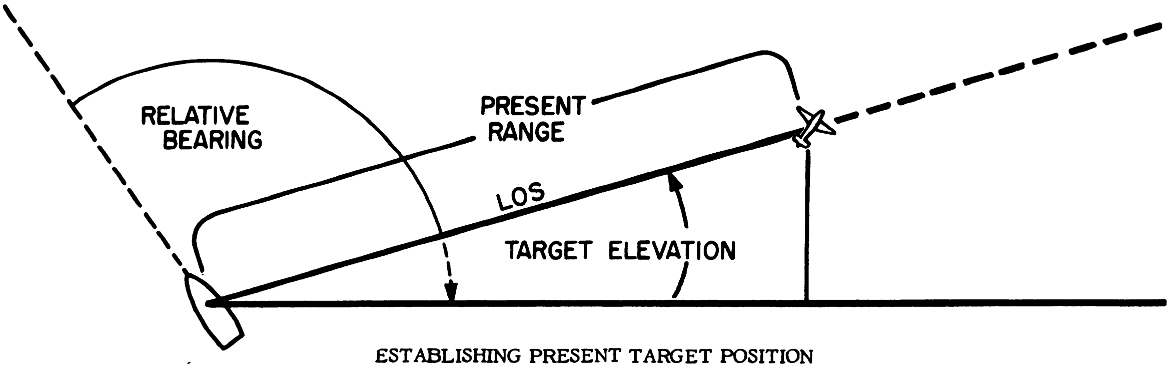
Any fire control system has to establish present target position. Many systems measure target bearing, elevation, and range. The GFCS Mk 51 establishes present target position by aligning the gun sight line of sight on the target.



TARGET POSITION IN TRAIN

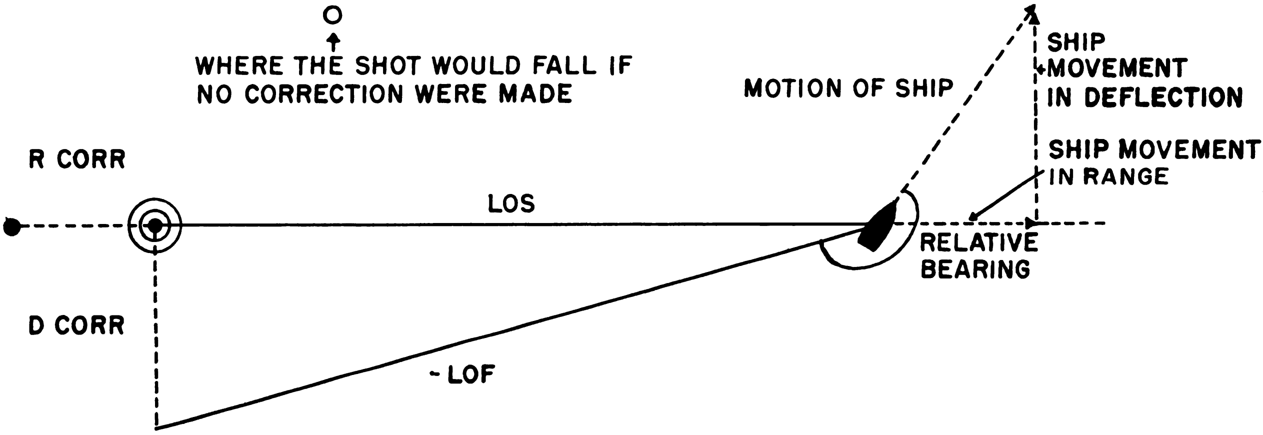


TARGET POSITION IN ELEVATION



ESTABLISHING PRESENT TARGET POSITION

Own ship's motion is established by own ship's course and own ship's speed in and across the line of sight in many surface and dual-purpose systems. Own ship's motion imparts force on the projectile which would cause the projectile to miss the target if not corrected for. If own ship is moving toward the target and the gun is fired without being corrected for own motion, the projectile would land beyond the target, so range has to be decreased to correct for this error. Likewise, if own ship is moving away from the target, range is increased to correct for own ship's motion. Own ship movement to right would cause the projectile to fall to the right of the target, so the correction in deflection is to the left. Likewise, own ship movement to the left would cause the projectile to fall to the left of the target, so the correction in deflection is to the right.

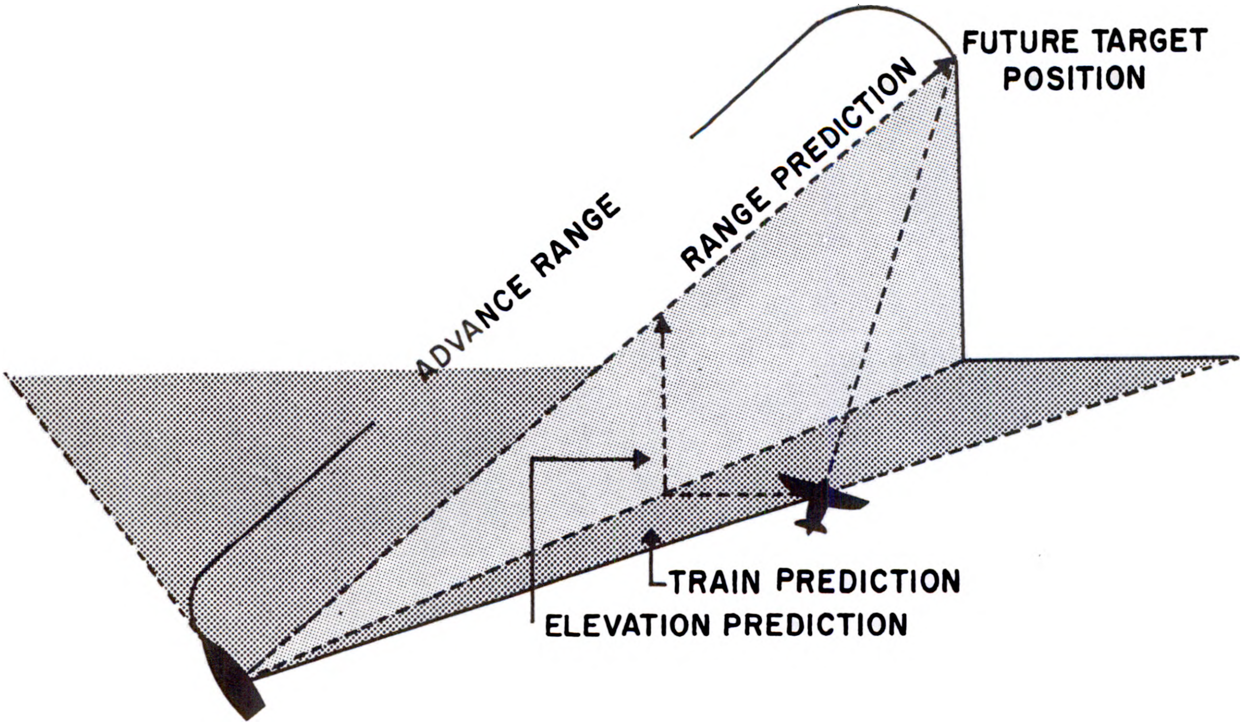


OWN SHIP'S MOVEMENT EFFECT ON THE PROJECTILE

The GFCS Mk 51 is corrected for own ship's motion as the director operator keeps the gun sight on the target.

Target motion is established by target course and speed components in and across the line of sight. On air targets, a vertical component of target motion is present. If the target stays on the same course and speed at the end of time of flight, it should occupy the predicted future target position. The future target position is the place occupied by the target at the instant the projectile scores a hit.

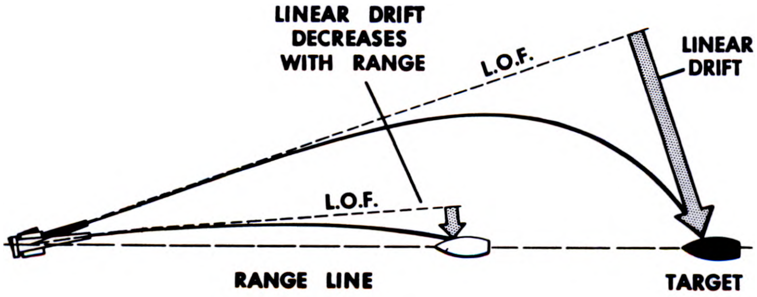
In several systems, own ship and target motions make up train, elevation, and range predictions.



TRAIN, ELEVATION AND RANGE PREDICTIONS

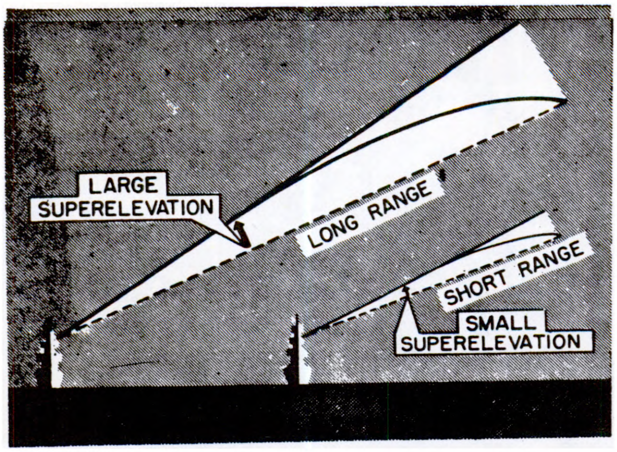
In the GFCS Mk 51, lead angles are generated in traverse and elevation by two rate-of-turn gyros in Gun Sight Mk 14.

To establish a line of fire, corrections are added to the prediction in some systems. Drift of the projectile to the right necessitates a left correction to train. Drift is very small at short ranges and increases as range increases. Due to such short range, Gun Sight Mk 14 is not corrected for drift.

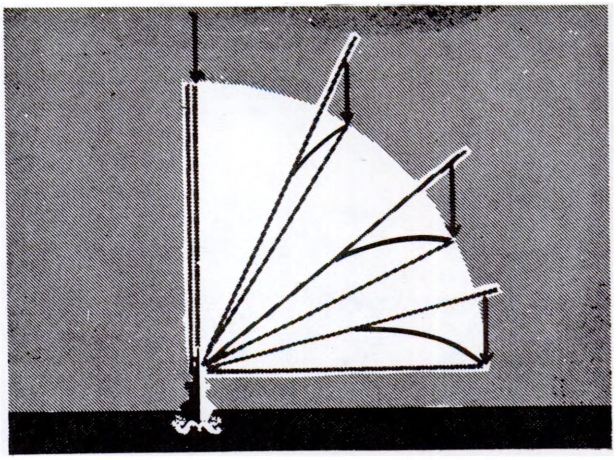


DRIFT

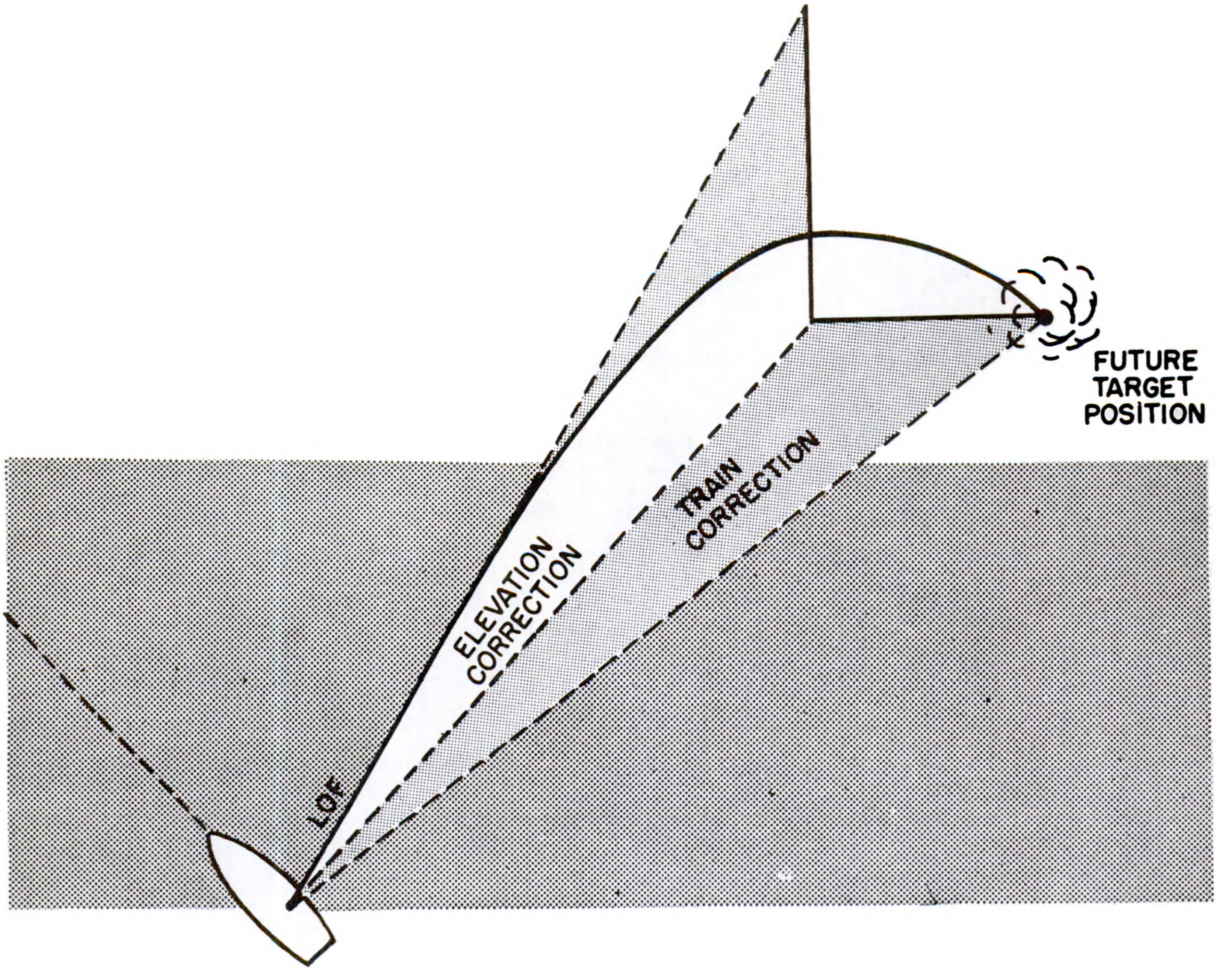
Superelevation is the correction for the effect of gravity on the projectile and makes up the major part of elevation correction. Superelevation correction is always positive, or up, because gravity pulls down on the projectile. It increases as range increases and decreases as elevation increases.



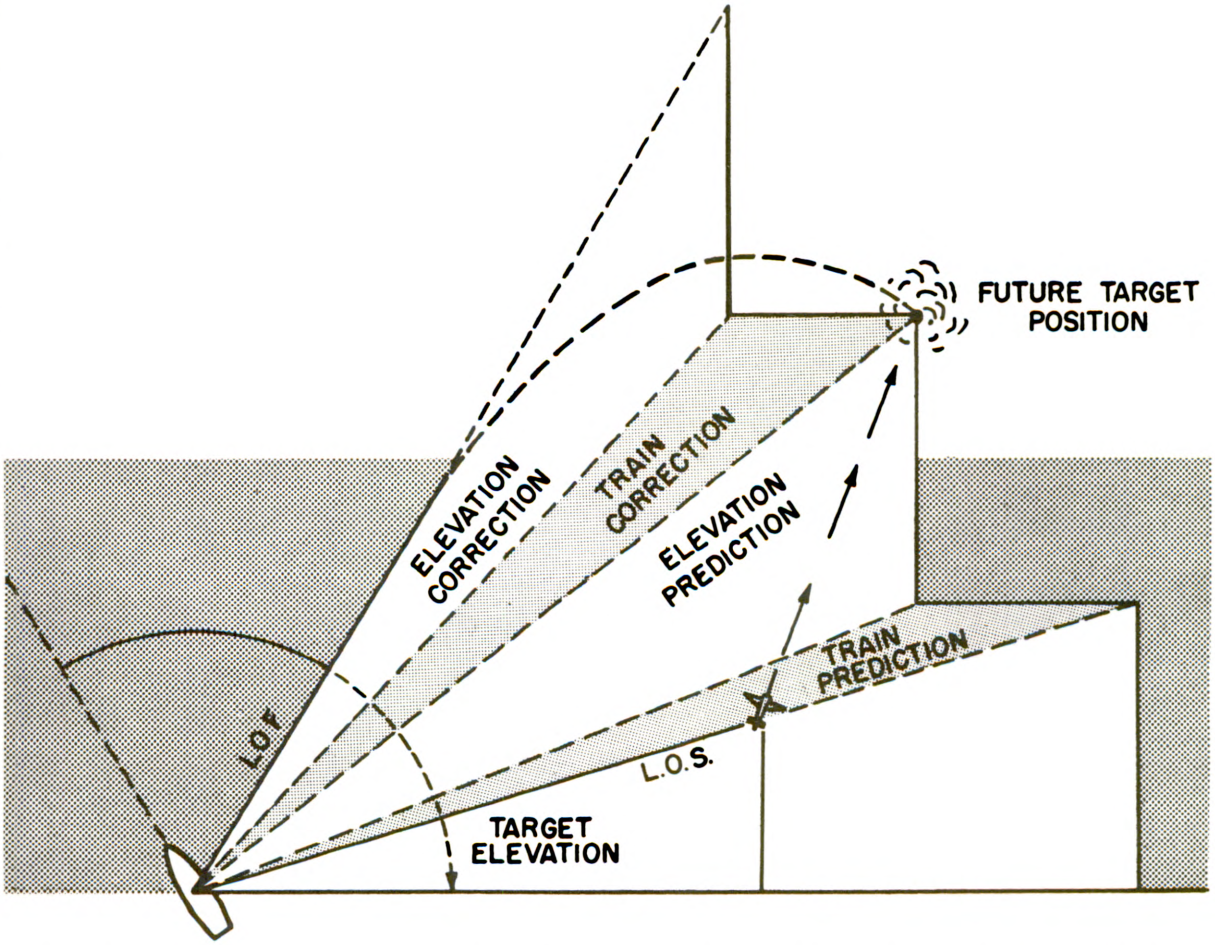
RANGE EFFECT ON SUPERELEVATION



ELEVATION EFFECT ON SUPERELEVATION



TRAIN AND ELEVATION CORRECTIONS



In this sketch the present position of the target is established, predictions added, and the corrections made.

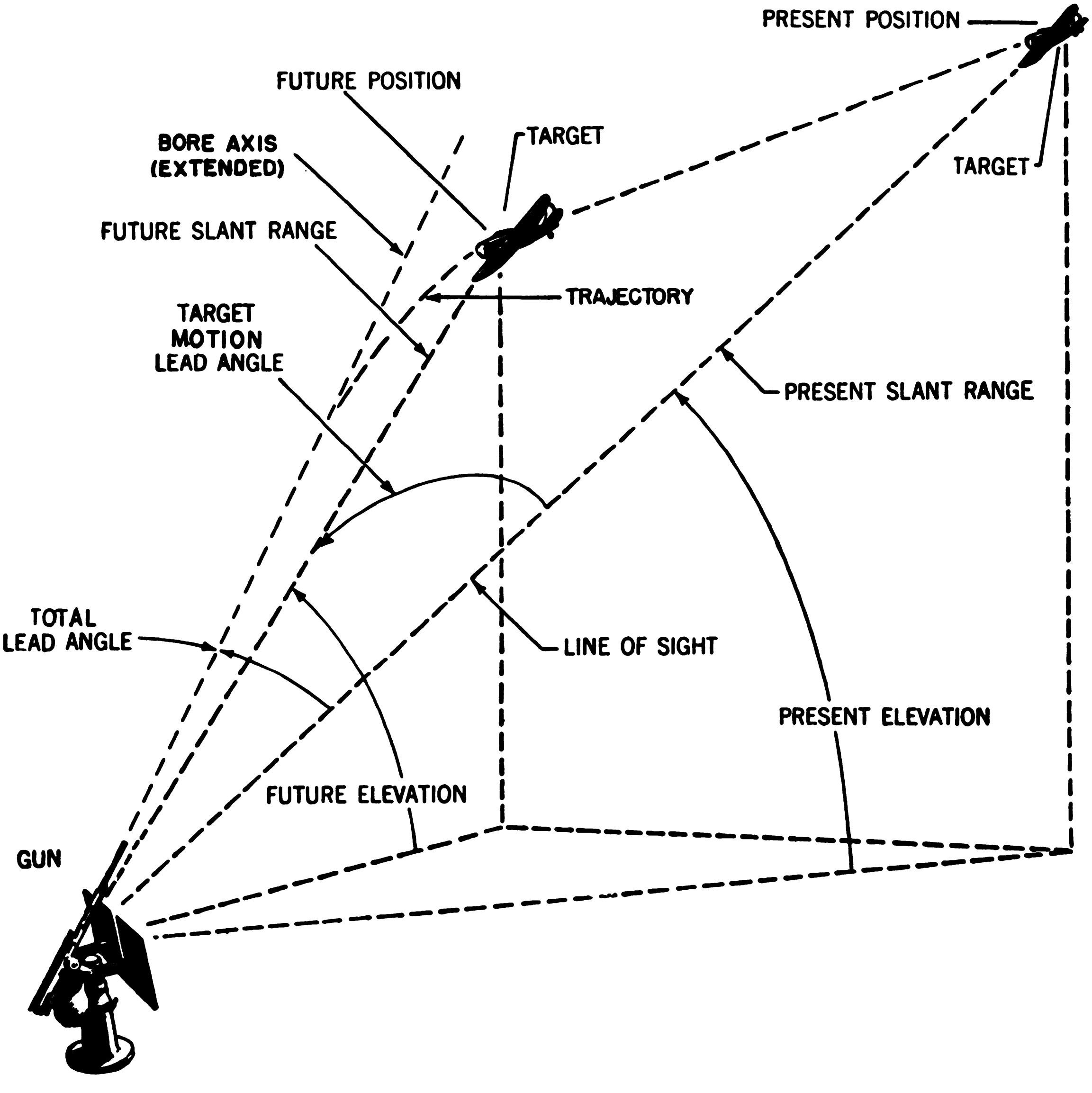
Gun orders are made up in fire control computers, such as Gun Sight Mk 14. These gun orders are then transmitted to, and received by, the guns by electrical means. There are three gun orders: gun train order, gun elevation order, and fuze order. A breakdown of gun train order and gun elevation order follows. Fuze order times the projectile burst, but will not be taken up here because 40-mm projectiles burst on contact.

To compute gun train order, the present target position is measured in degrees and minutes from the bow of own ship clockwise to the line to sight. The train predictions caused by own ship and target motion during time of flight are added algebraically to present target position in train. In other words, train prediction may be added to, or subtracted from train angle. Train correction is the final portion of gun train order and is made up primarily of drift. Drift in all naval guns is to the right, therefore train correction is negative, or to the left.

The GFCS Mk 51 arrives at gun train order in a slightly different manner. As the director operator tracks the target, the director leads the gun sight line of sight. Director train is equal to gun train order.

To compute gun elevation order, the present target position in elevation is measured from the horizontal to the line of sight. The elevation predictions caused by own ship and target motion during time of flight are added algebraically to target elevation. Elevation correction is the final portion of gun elevation order and is made up primarily of superelevation. Superelevation correction is always positive.

Gun elevation order in the GFCS Mk 51 is computed by the gun sight and director and corresponds to the position of the director tracking head in elevation.



Some relative rate systems offset the fore and aft axis of the sight case by the amount of computed lead angle, so that the sight case is aligned with the gun bore axis. These systems are known as DISTURBED-LINE-OF-SIGHT systems. Most lead-computing systems, such as the GFCS Mk 51 are of this type.

Tracking the usual air target calls for lead in both traverse and elevation to compensate for target motion during the time of flight. The angular velocity of the line of sight, when measured accurately and adjusted for time of flight and for ballistic corrections, becomes the total lead angle. More precisely, the total lead angle may be defined as the angle between the LOS to the present target position and the position of the bore axis required to hit the target at the end of the time of flight.

Target-motion lead angle is the angle between the LOS to present target position and the line from gun to target at the end of the time of flight. This target-motion lead angle is ordinarily made up of an elevation component perpendicular to the deck plane and a traverse (train) component measured in the traverse plane. The traverse plane is the slant plane containing the gun sight trunnion axis and the present position of the target.

The gun bore can not be pointed directly at the future target position, because of the pull of gravity on the projectile. The angle at which the gun must be elevated to compensate for the effect of gravity is called superelevation, and depends on range, I.V., and elevation.

Gun train order and gun elevation order, position the gun in the line of fire. When these quantities are correct, a hit will be scored.

There is no correction for the errors caused by the wind blowing on the projectile in the GFCS Mk 51. You may come in contact with other systems having wind corrections, so a brief explanation is given here. Wind effect is corrected for in the prediction section where it is combined with the relative motion of own ship and target.

True wind is the wind as it exists with respect to the earth and is independent of own ship's motion. Ballistic wind is always used as the input to Fire Control systems, when it is available. It is a value of wind speed and direction which is considered to be the resultant of the effect of all the true winds at various altitudes acting upon the projectile in flight. Winds at various altitudes generally differ in force and direction from true wind at the surface.

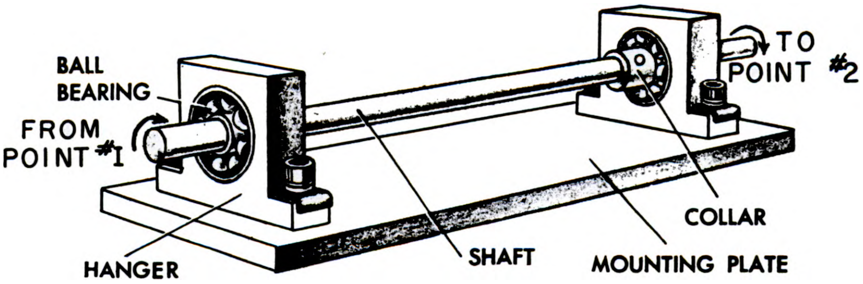
Own ship's movement imparts motion to the projectile, and this motion of the projectile through the air causes a wind to exist similar to the wind felt by a boy riding a bicycle fast on a still day. Even though there is no true wind, there is definitely a wind blowing in the boy's face. Apparent wind is the wind which is apparent to own ship which is itself in motion. It is the result of the motion of the true wind and the reversed motion of own ship.

Own ship and target are constantly in motion, therefore, correct gun orders at one instant would be incorrect the following instant. The Fire Control problem has to be constantly changing to keep the guns hitting the target. The process of continually solving the fire control problem is called generating. The process of generating range, relative bearing, and elevation requires the determination of range rate, angular bearing rate, and angular elevation rate. These rates are a measure of how fast a quantity is changing. Range rate is defined as rate of change of range along the line of sight. Elevation rate is the rate of change of elevation and may be a linear or angular rate depending upon the type of computer, or section of the computer in which it is present. Bearing rate is the rate of change of bearing. As in elevation rate, the bearing rate may be a linear or angular rate.

In the GFCS Mk 51, these rates are not present as separate quantities but are generated by the sight operator tracking the target. More about the fire control problem as solved by Gun Sight Mk 14 will be taken up at a later time.

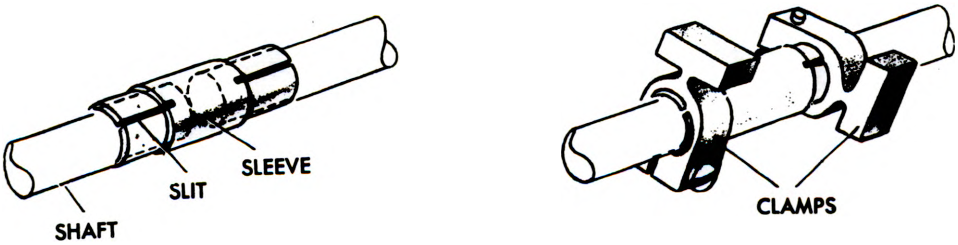
BASIC MECHANICAL UNITS

Throughout fire control equipment, mechanical units are used for many different purposes.



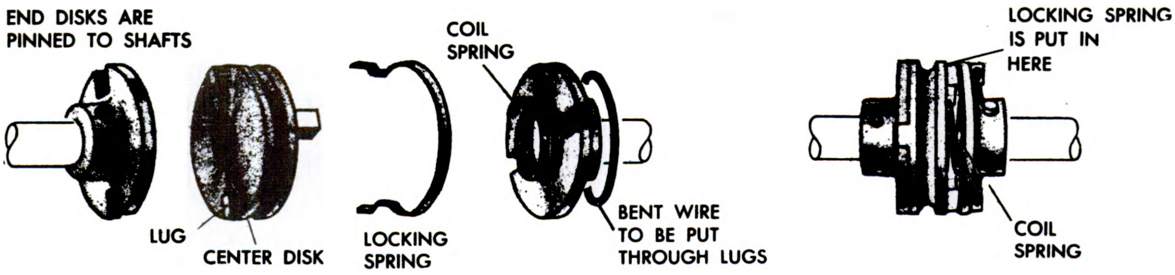
SHAFT ASSEMBLY

A shaft transfers motion from one point to another. Most shafts are straight, but occasionally a flexible shaft is used where motion can't be transferred in a straight line. The reduction of friction on these shafts and on other units is accomplished by ball bearings, or sometimes by roller bearings.



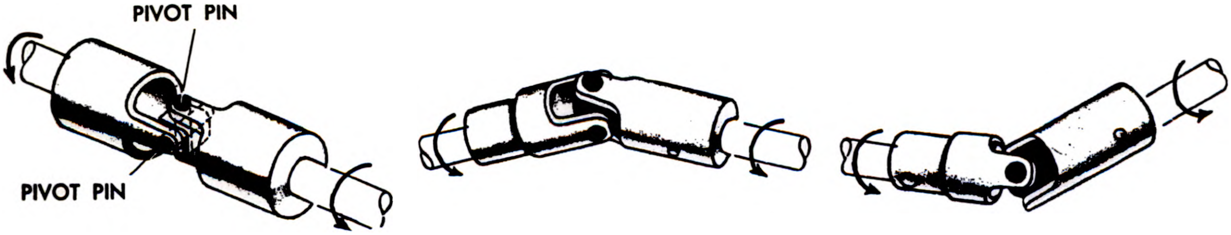
SLEEVE COUPLING

Coupling devices are used to couple shafts end to end, and are of three major types. The sleeve coupling is used to join two shafts that lie in a straight line. These couplings are secured to the shaft ends by balanced clamps.


END DISKS ARE PINNED TO SHAFTS
LUG
CENTER DISK
LOCKING SPRING
COIL SPRING
BENT WIRE TO BE PUT THROUGH LUGS
LOCKING SPRING IS PUT IN HERE
COIL SPRING

OLDHAM COUPLING

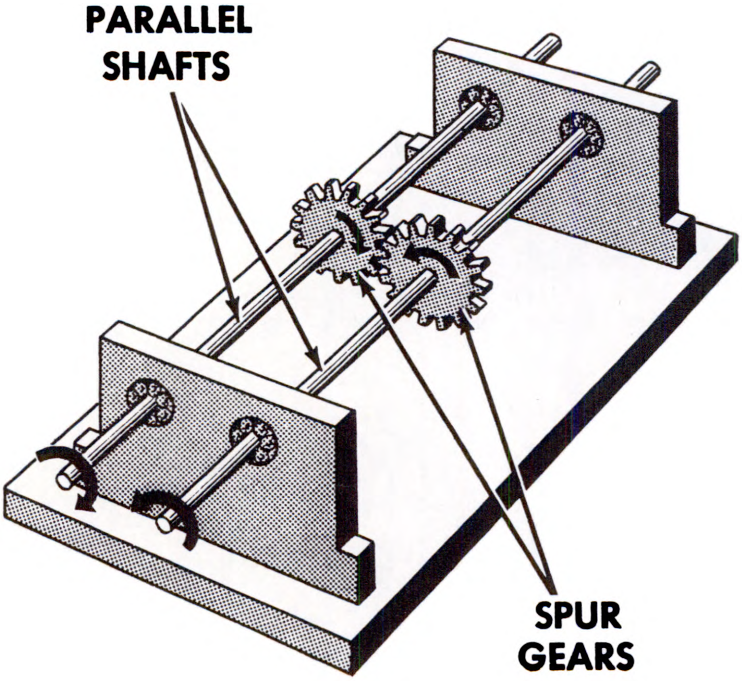
The Oldham coupling is used to join two shaft ends that are not in perfect alignment, and is secured to the shaft ends by pins.



UNIVERSAL JOINT

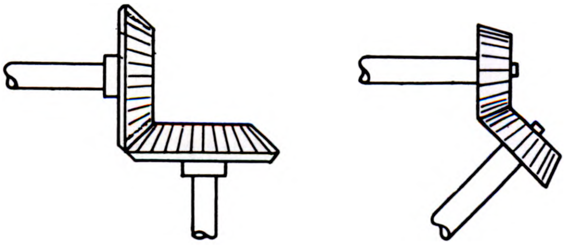
A universal joint is used to connect two shafts that lie at an angle to each other and it also is secured to the shaft ends by pins.

Gears are of many types and descriptions. You will see and use these frequently while in fire control.



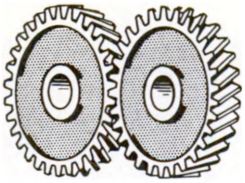
SPUR GEARS

The straight spur gear is used to join two parallel shafts. They have mating teeth cut into their surfaces so that one can turn the other without slippage.



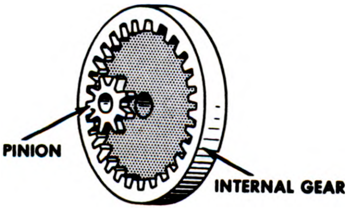
BEVEL GEARS

Bevel gears are used to transmit motion between two shafts lying at any given angle, because they can be beveled to suit the angle.



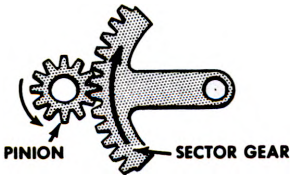
HELICAL SPUR GEARS

Helical gears, also called spiral gears, lessen the lost motion and also provide smoother and quieter action.



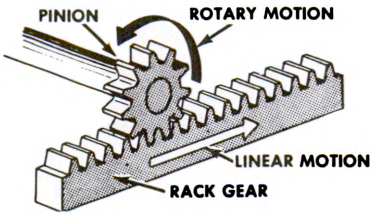
SUN GEAR

The sun gear is a combination of two gears, one large gear with teeth cut on its inner surface, and a smaller straight spur gear which is meshed with the teeth of the internal gear.



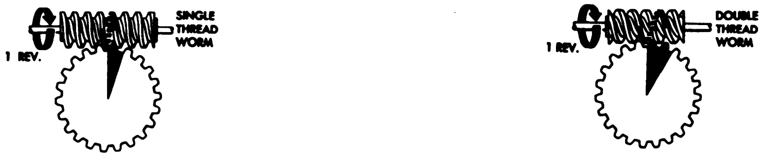
SECTOR AND PINION GEAR

Sector and pinion gears are used where only a portion of a gear is needed and motion of the pinion is limited. Sector gears are also used to save space and material.



RACK AND PINION

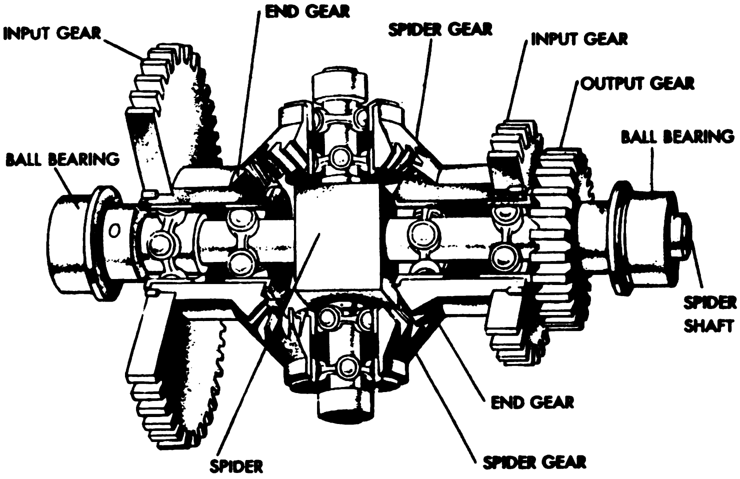
The gears up to this point have all been moving in a rotary or circular motion. In some fire control mechanisms, linear, or straight-line motion is desired. This conversio of rotary motion to linear motion, or vice versa, is accomplished by a rack and pinio gear. The pinion of this gear type is like all pinions taken up so far. The rack type is a straight bar on which gear teeth have been cut.

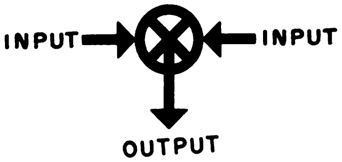


WORM AND WORM WHEEL

The worm and worm wheel gear is also used throughout fire control. The worm gear is one with threads cut into its surface much like the threads of a screw. The worm wheel is a type of spur gear whose teeth are cut to mesh with the threads of the worm gear. The large gear ratio of the worm and worm wheel produce large speed reductions, thus permitting a small electric motor to drive a large load.

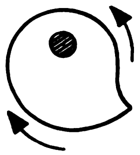
This type gear is also irreversible,--or the worm can drive the worm wheel, but the worm wheel cannot drive the worm.





BEVEL-GEAR DIFFERENTIAL

The differential, as used in Fire Control, is a type of computing device. It can add or subtract two quantities. The schematic representation of the differential is a circle with a cross in it.



FLAT CAM

The flat cam is used to operate mechanical devices to control electrical units such as relays and switches; mechanical units such as the valves in the engine of a car; and hydraulic units as found in some power drives.

JOB SHEET NO. 8

In fire control, to define certain values and terms, symbols are used. There are many of these symbols in use, and the few below are among the more important ones.

Learn the symbols, nomenclature, and their definitions because you will see and use them many times in the future.

Instructions: Fill in symbols and their definitions.

1. _______ Own ship's speed _______

2. _______ Own ship's course _______

3. _______ Director train _______

4. _______ True target bearing _______

5. _______ Target angle _______

6. _______ Target Horizontal ground speed _______

7. _______ Target course _______

8. _______ Target elevation _______

9. _______ Observed present range _______

10. _______ Superelevation _______

11.________Gun train order____

12.________Gun elevation order____________________________________

ACCURACY AND PRECISION

Because of the nature of the fire control problem and the values used in solving this problem, accuracy and precision are of prime importance. One example of the need for accuracy would be if the range to the target were 24,000 yards and the gun elevation order was in error by 10 minutes, or 1/6 of a degree, the projectile would miss the target by 210 feet. Friction must be kept to an absolute minimum. The ball bearings used by the Navy in fire control must be perfect; in fact, out of every one thousand manufactured only three are found to be acceptable for use in fire control.

In making up the final orders to the guns, hundreds of computations and measurements are used, and if errors are present they accumulate or multiply. Therefore, the accuracy of each computing or measuring device must be even greater than the accuracy of the final product.

Accuracy also is demanded of the instruments used in making adjustments. You can have the most accurate instrument available do you no good, if the adjustment you make is not correct. Accuracy is achieved only by the use of precision-built instruments, and by making precise adjustments.

COMPOSITION OF A FIRE CONTROL SYSTEM

A fire control system is a combination of units needed to direct the projectile to the target. The typical fire control system is composed of five parts. The first is the director, which must establish and maintain the line of sight. Next is the stable element, which is used to provide the necessary stabilization. Computation of the fire control problem is next and this is done by a computer. The switchboard is fourth, and it is used to provide the necessary switching arrangement, or to select the gun or guns that are to be used. Last is the gun, which must fire the projectile.

SECTION II

ELECTRICITY FUNDAMENTALS

Topic No.	Topic Title	Sheet
1.	Introduction to Electricity	II-1-1
2.	What Electricity Is	II-2-1
3.	How Electricity Is Produced.	II-3-1
4.	Current Flow.	II-4-1
5.	Electromotive Force.	II-5-1
6.	Resistance	II-6-1

SECTION II

TOPIC 1

INTRODUCTION TO ELECTRICITY

A. You have learned:	References
1. The scope of this course.	
2. Introduction to Fire Control.	
B. You are learning:	
1. What Electricity is	NavPers 10622-B, pages 1-7
a. Construction of Matter.	
b. Electron Theory.	
2. How Electricity is Produced	NavPers 10622-B, pages 9-26
a. Static Electricity.	
b. Dynamic Electricity.	
c. Six Sources of Electricity.	
3. Current Flow	NavPers 10622-B, pages 17-26
a. Propagation of Free Electrons.	
b. Direction of Current Flow.	
c. How Conventional Current Flow Differs	
4. Electromotive Force	NavPers 10622-B, pages 11-23
a. Potential and Voltage.	
b. Voltage and Current.	
5. Resistance	
a. Factors Controlling Resistance	NavPers 10622-B, pages 20-26
b. Insulators.	NavPers 10622-B, pages 21-22
c. Units of Resistance and Resistive Devices.	NavPers 10622-B, page 56, NavPers 10170 Vol. 1., pages 18-23
d. RMA color code.	NavPers 10170 Vol. 1., pages 27-30
6. Power Drive Mk 4	OP 821-A, pages 39-74
a. Amplidyne Generator and Drive Motor.	
b. Control Unit.	
c. Amplifier.	
d. Drive Unit.	
e. Drive Motor.	

WHAT ELECTRICITY IS

Electricity is the power that makes all types of fire control equipment work; such as motors, telephones, radar, amplidyne drives, lights; directors, computers, and all other electrical equipment. To understand electricity, the construction of matter has to be understood. All matter, in its natural state, is made up of molecules which can be broken down into two or more substances called atoms. The atoms are made up of the electrons, protons, and neutrons. The electron theory deals with the flow of electrons from one atom to another.

HOW ELECTRICITY IS PRODUCED

Static electricity is electricity at rest. Dynamic electricity is electricity in motion. There are six sources of electricity--friction, pressure, heat, light, chemical action, and magnetism. Only chemical action and magnetism will be elaborated on.

CURRENT FLOW

Current flow is the propagation of electrons, or the movement of free electrons from one atom to the adjacent atom. An excess of electrons is called a negative charge, and a deficiency in electrons is a positive charge. Electron flow is always from negative to positive. The old conventional current flow theory where current flows from positive to negative is seldom used.

ELECTROMOTIVE FORCE

EMF is the force that makes electrons move. Potential is a reserve of electrical energy and may be used to exert a force. It is always in relation to another charge or point. Voltage is a difference in potential that exists between any two charges that are not equal. Whenever two points of unequal charge are connected, a current flows from the more negative to the more positive charge. The greater the emf or voltage between the charges, the greater the amount of current flow.

RESISTANCE

Resistance is the opposition of a material to current flow. The amount of resistance depends on the number of free electrons in the material. Copper has more free electrons than iron, so iron has the greater resistance.

The longer a piece of wire, the more the resistance of the wire. A wire with a large cross-sectional area has less resistance than a wire with a smaller cross-sectional area.

A good conductor is usually a metal that has many free electrons. Sometimes a gas is used as a conductor. In other words, any material through which current flows easily, is a good conductor.

There has to be a material that stops, or almost stops the flow of electrons. Otherwise, no electrical equipment would work. This material is known as an insulator. A good insulator has few free electrons and offers much opposition to the flow of current and therefore is used to block or ''insulate'' against the flow of current.

The unit of resistance is the ohm. When one volt causes one ampere of current to flow, the resistance is one ohm. There are many different types of resistance devices, but they are all very simple. A resistor with a small resistance value may offer only a fraction of an ohm resistance to current flow. A resistor with a large resistance value may offer millions of ohms resistance to current flow. Resistance devices are divided into several classifications. Some of them are: type, size, wattage rating, resistance, and mounting.

Many resistance devices, or resistors as some of them are called, are physically too small to print on the values, so a color code is used to designate resistance and tolerance. The physical size designates the wattage, or power rating, of many resistors.

There are five major units of the Power Drive Mk 4. The amplidyne generator is used to generate controlled d-c power to the gun mount drive motor. The control unit contains all electrical control devices for both the train and elevation power drives. The amplifier unit contains the amplifiers for both the train and elevation power drives. The drive unit is a combination of electrical and mechanical devices used to position the gun in train or elevation in response to ordered signals. The drive motor actually positions the gun mount in train and elevation.

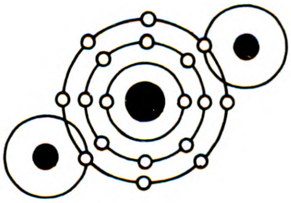
SECTION II

TOPIC 2

WHAT ELECTRICITY IS

A. You have learned:	References
1. The scope of this course.	
2. Introduction to Fire Control.	
3. Introduction to Electricity.	
B. You are learning:	
1. About the Construction of Matter.	NavPers 10622-B, pages 1-7
2. About Electrons and Electricity.	NavPers 10622-B, pages 1-7
3. The Electron Theory.	NavPers 10622-B, pages 1-7

CONSTRUCTION OF MATTER



MOLECULE--THE COMBINATION OF TWO OR MORE ATOMS

MATTER--a drop of water

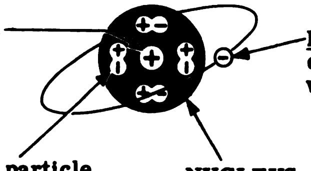
All matter, everything around you, has "weight" and "occupies space."

You have heard that electrons are tiny particles of electricity, but you may not have a very clear idea of the part electrons play in making up all the materials around us. You can find out about the electron by carefully examining the composition of any ordinary material--say a drop of water. If you take this drop of water and divide it many thousands of times till you have the smallest particle of water possible, you will have one molecule of water. You couldn't see this molecule even with the most powerful microscope made. This molecule of water still has all the chemical characteristics of the drop of water, but if you divide it any further, it will cease to have the characteristics of water and take on new form. The molecule of water is composed of three parts closely bonded together, two tiny structures that are the same, and a larger structure that is different from the two. These tiny structures are called atoms.

The two tiny atoms which are the same are hydrogen atoms, and the larger different one is an oxygen atom. When two atoms of hydrogen combine with one atom of oxygen, you have a molecule of water.

While water is made up of only two types of atoms, oxygen and hydrogen, the molecules of many other materials are more complex in structure. All materials are made up of

ATOM—The smallest physical particle into which an element can be divided.



PROTON—The heavy positively-charged particle in the nucleus.

ELECTRON—The very small negatively-charged particle which is practically weightless and circles the nucleus.

NEUTRON—The heavy neutral particle in the nucleus consisting of a proton and an electron.

NUCLEUS—The heavy positively-charged part of the atom which does not move.

ELECTRICITY—The effect of electrons in moving from point to point, or the effect of too many (excess) or too few (lack of) electrons in a material.

different combinations of atoms to form molecules of the materials. There are only about 100 different kinds of atoms, and these are known as elements. Oxygen, nitrogen, carbon, iron, copper, silver, and gold are just a few of the elements.

Let us break down one of the atoms you find in the water molecule. The smallest is the hydrogen atom which is like a sun with one planet spinning around it. The planet is known as an "electron," and the sun is the "nucleus." The electron has a negative charge of electricity, and the nucleus has a positive charge of electricity.

In an atom, the total number of negatively charged electrons circling around the nucleus exactly equals the number of extra positive charges in the nucleus. The positive charges are called "protons." Besides the protons, the nucleus also contains electrically neutral particles called "neutrons", which are made up of a proton and an electron bonded together. Atoms of different elements contain different numbers of neutrons within the nucleus, but the number of electrons spinning about the nucleus always equals the number of protons within the nucleus that are not bonded to electrons.

"Bound electrons" are electrons in the inner orbits of the atom, which cannot easily be forced out of their orbits. "Free electrons" are electrons in the outer orbits of the atom, which can easily be forced out of their orbits. "Electricity" is the effect of electrons in moving from point to point, or the effect of too many (excess) or too few (lack of) electrons in a material.

ELECTRONS AND ELECTRICITY

Electrons travel around the nucleus of an atom and are held in their orbits by the attraction of the positive charge in the nucleus. If you could somehow force an electron out of its orbit, then the electron's action would become electricity. Electric current flow is the movement of free electrons (negative charges) through a material.

There are many kinds of matter. Rubber, glass, plastic, neoprene, and bakelite, have very few "free electrons," so electric current will not flow through them easily. Materials such as copper, silver, and aluminum have many free electrons, so electric current will flow through them easily.

THE ELECTRON THEORY

All electrical and electronic effects are explained by the "electron theory." Electricity is the effect of electrons flowing in a material or an excess or lack of electrons in a material. Any material having an excess of electrons has a "negative charge" because the electron itself is negative. Any material having a lack of electrons has a "positive charge" because it has more protons than electrons. The main point of the electron theory is that electrons flow from negative to positive materials when given a path to flow through.

SECTION II

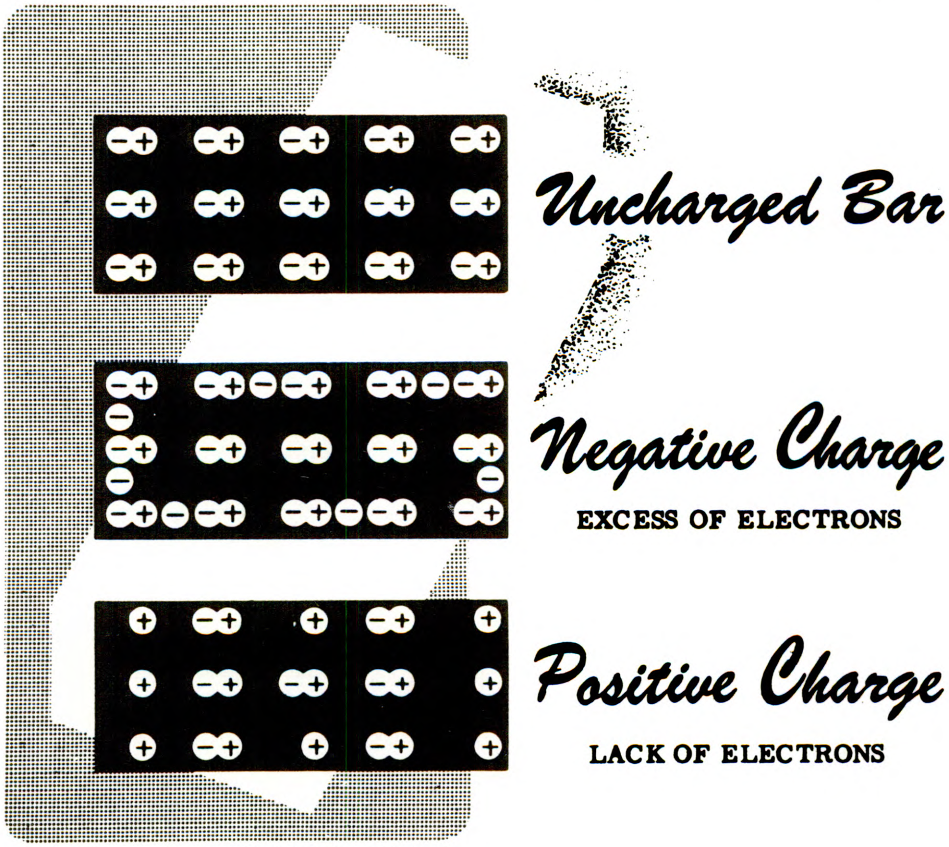
TOPIC 3

HOW ELECTRICITY IS PRODUCED

A. You have learned:	References:
1. The scope of this course.	
2. Introduction to Fire Control.	
3. Introduction to Electricity.	
4. About the Construction of Matter.	
5. The Electron Theory.	
B. You are learning:	
1. About Static Electricity.	NavPers 10622-B, pages 9-16
2. About Dynamic Electricity.	NavPers 10622-B, pages 17-19
3. The Sources of Electricity.	NavPers 10622-B, pages 43-53
4. How Electricity is produced in the Power Drive Mk 4.	OP 821A, page 26

STATIC ELECTRICITY

Static electricity is electricity at rest and is produced by induction or friction. A static charge may be negative or positive. A negative charge is an excess of electrons in



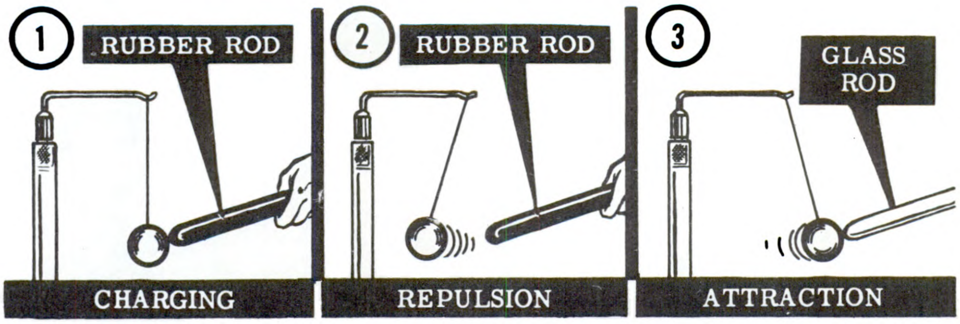
a material. A positive charge is a deficiency of electrons in a material. If unlike charges are placed side by side, they attract each other. If like charges are placed side by side, they repel each other. When a material is discharged, it is said to be neutralized or uncharged.

DEMONSTRATION OF STATIC ELECTRICITY

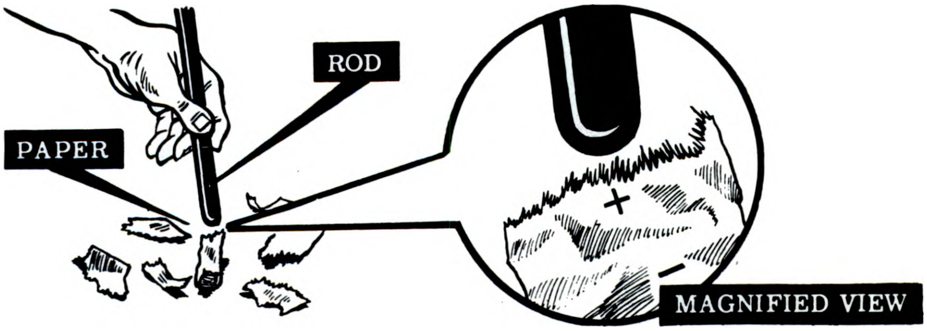
From the effects of static electricity as demonstrated, you can see how static charges behave and can be used.

First you will see how friction can be used to produce static electricity. If the humidity is low, you will be able to produce a positive charge in the glass rod by rubbing with the silk pad, or a negative charge in the rubber rod by rubbing with the fur pad.

To show that charges exist after rubbing, assemble the pith ball support with a pith ball attached to the support arm so that it will swing freely. Bringing a charged rubber rod near the pith ball, you will see that it is first attracted to the rod, then is repelled as it assumes the same charge as the rod. When you charge the pith ball with the rubber rod, it will be repelled by that rod but attracted to the charged glass rod. This shows that the rods have opposite charges.

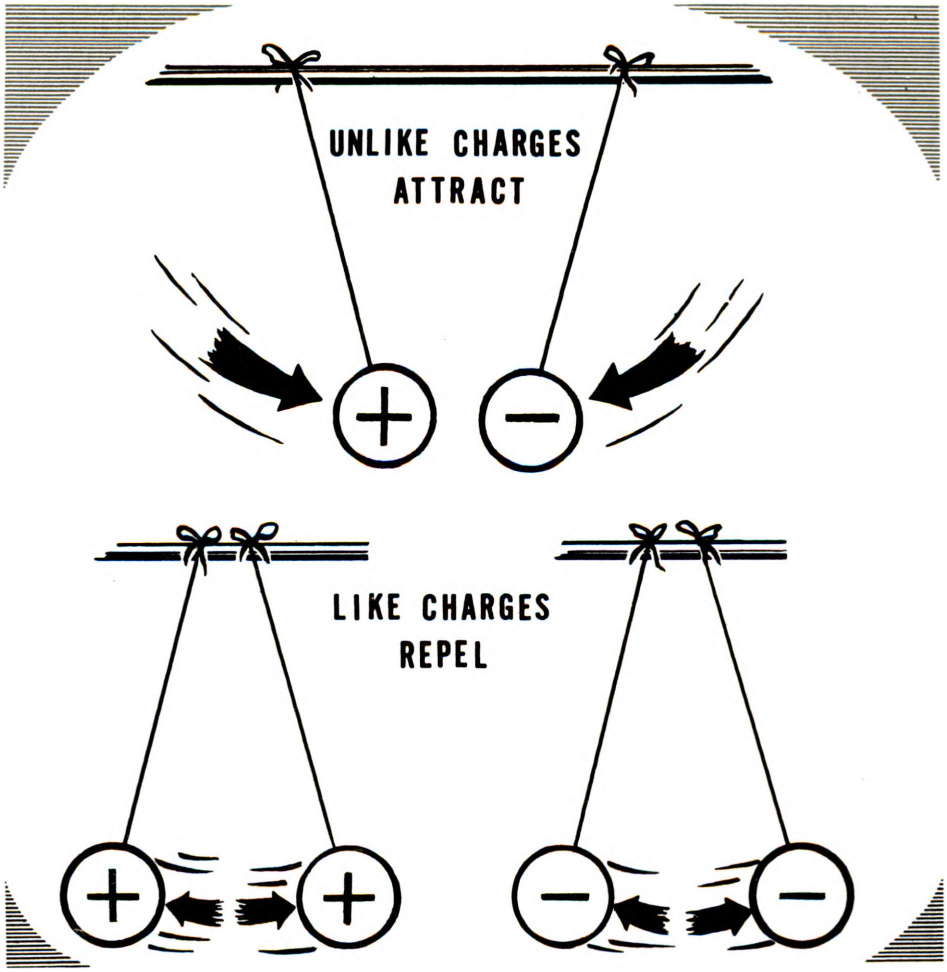


If the charges on the rods are not large enough to show these effects with pit balls, you may be able to produce the effects by using small scraps of soft paper, torn so that the edges are not smooth. In observing the effects of charges on paper scraps, remember that when a charged rod is brought near a paper scrap, the first force is attraction. If the paper becomes charged by the rod, it will then be repelled by that rod.



Using paper scraps you will see the force of attraction most clearly if the charged rod is touched to a very jagged edge of the torn paper. The rough edge of the paper will prevent the rod and paper from making a good contact so that the rod cannot transfer its charge to the paper. Instead, the charge induced into the edge of the paper near the rod will be the opposite of that on the rod, resulting in a force of attraction.

Attach another pith ball to the support arm and you will see that when they are charged by the rubber rod, they will repel each other.



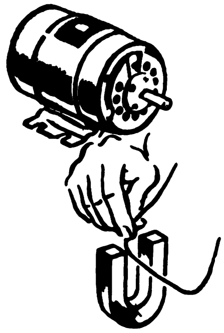
A charge may be discharged by providing a path to a material that will absorb or supply the necessary electrons. To discharge a positive charge, electrons are supplied. To discharge a negative charge, electrons are absorbed by another material. When a charge is discharged through the air, an arc or spark is formed.

A capacitor is the most useful application of static charges. The capacitor has the ability to stow an electric charge for practical uses.

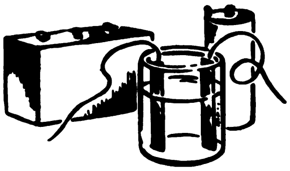
DYNAMIC ELECTRICITY

Dynamic electricity is electricity in motion, or current flow. Current flow is the directional movement of millions of electrons through a material. The material through which the current flows is called the circuit.

SOURCES OF ELECTRICITY



MAGNETISM

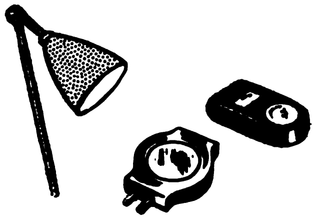


CHEMICAL ACTION

FRICTION

PRESSURE

HEAT



LIGHT

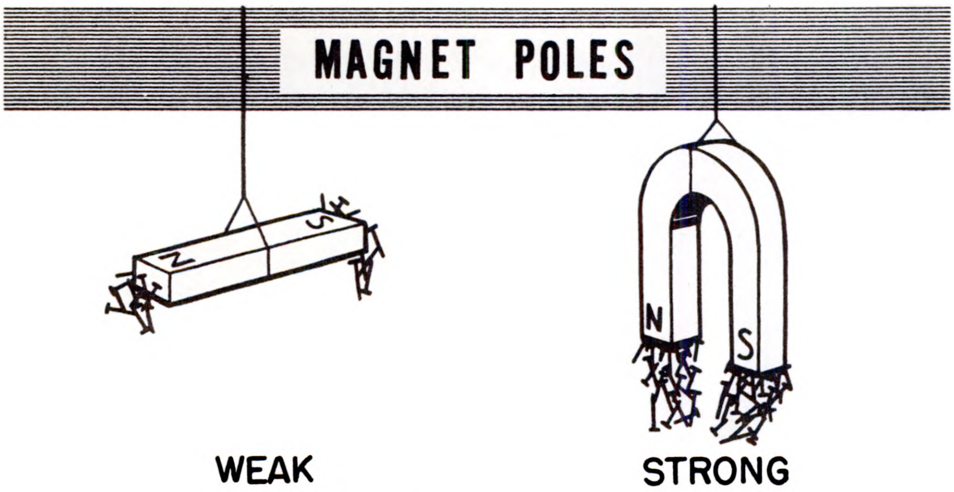
Heat produces electricity when a junction of two dissimilar metals such as copper and iron is heated. Some electrical meters use this principle.

Light produces electricity when it strikes certain photosensitive materials. The photoelectric cell is one example of this principle.

Friction produces electricity by giving up or collecting electrons. Gasoline trucks are grounded to discharge any charge that is generated by the truck passing through the air. All fire control electrical and electronic equipment has to be grounded so that the static charge may leak off to the ground.

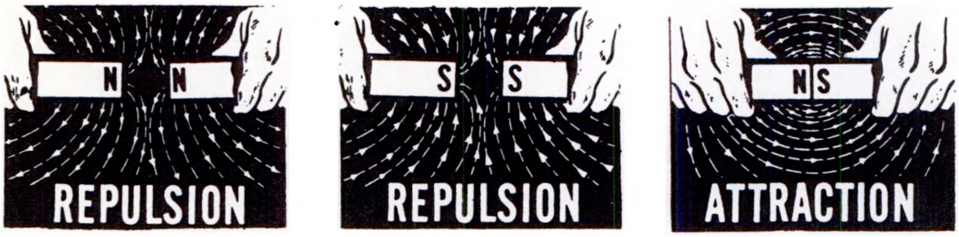
Chemical action produces electricity. Electrons are forced to move through an electrolyte by chemical action of two dissimilar plates in the electric cell. Two or more of these cells in one unit is called a battery. Primary cells are cells that cannot be recharged and secondary cells are cells that can be recharged. The Navy uses primary cells in flashlights, battle lanterns, portable radios, and many other types of equipment. Fire Control Technicians come in contact with secondary cells in emergency firing and lighting circuits, reference batteries, etc. Secondary cells are usually heavier and furnish more power than primary cells.

DO NOT SMOKE in the vicinity where batteries are being charged. A spark or fire may cause an explosion of hydrogen gas which is a product of the recharging process. BE CAREFUL when handling batteries. The acid in the electrolyte may give you a bad burn and ruin your uniform.



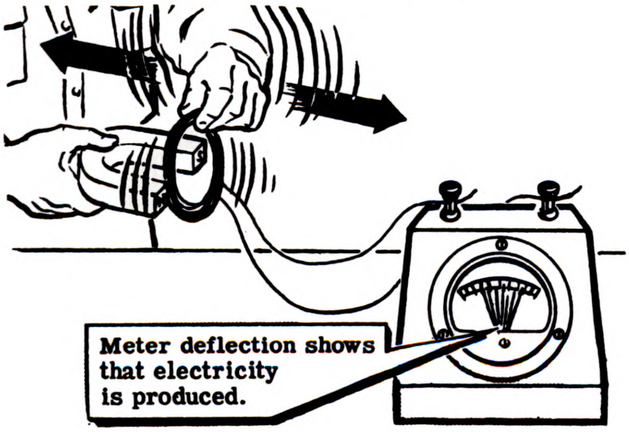
MAGNETISM--A PROPERTY THAT ATTRACTS IRON

Magnetisn is the most important source of electricity for large power applications. Magnetism is the force of attraction of magnets for iron. It is concentrated at two points. One point is a north pole, the other a south pole.

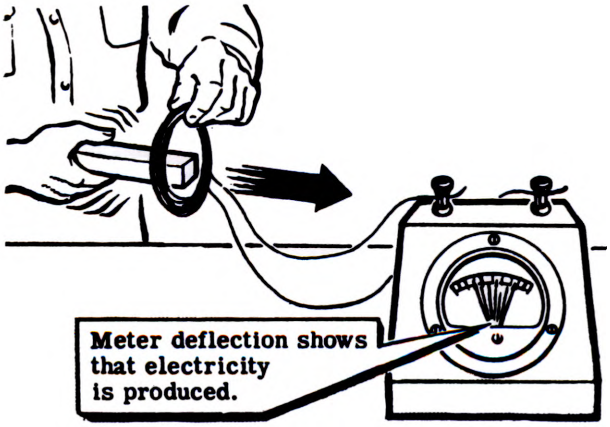


THE MAGNETIC FIELD

Like poles repel and unlike poles attract each other. Lines of force surround each magnet, leaving at the north pole and entering at the south pole.


Meter deflection shows that electricity is produced.

MOVING A COIL OF WIRE IN A MAGNETIC FIELD


Meter deflection shows that electricity is produced.

MOVING A MAGNETIC FIELD ACROSS A COIL OF WIRE

When a wire cuts magnetic lines of force, electricity is produced in the wire. Either the wire or the magnet may be moved so long as lines of force are cut. The amount of electricity produced depends on the number of turns of wire, strength of the magnet, and speed at which the magnetic lines of force are cut.

Electricity is produced in the power drive in four small generators, the train and elevation local power tachometers, and the train and elevation tachometer generators.

SECTION II

TOPIC 4

CURRENT FLOW

	References
A. You have learned:	
1. The scope of this course.	
2. Introduction to Fire Control.	
3. Introduction to Electricity.	
4. About the Construction of Matter.	
5. The Electron Theory.	
6. How Electricity is Produced.	
B. You are learning:	
1. About the Propagation of Electrons.	NavPers 10622-B, pages 17 to 19
2. Direction of Current Flow.	NavPers 10622-B, pages 17 to 18
3. Conventional Theory of Current Flow.	OP 821-A, page 50
4. Electron Theory of Current Flow.	NavPers 10622-B, pages 11 to 13
5. About Current Flow in the Power Drive Mk 4.	OP 821-A, page 50
6. Units of Measure of Current.	NavPers 10622-B, pages 19 to 20
C. You will acquire skill in:	
1. Tracing Current Flow.	OP 821-A, Fig. 19

PROPAGATION OF FREE ELECTRONS

Current flowing through a wire is surprisingly like water flowing through a pipe. As water goes into the pipe at one end, water moves throughout the pipe, and the same amount of water goes out the other end. The water that came out of the pipe wasn't the same water that went in at the same time. When current flows through a wire, free electrons are moving from atom to atom throughout the wire similar to water moving through the pipe. When current stops flowing, all the electrons stop their directional movement similar to the condition of water in a pipe when the faucet is closed.

Actually, there are millions of free electrons hitting atoms and knocking other electrons out of their orbits. These electrons that are knocked out of the atoms in turn hit other atoms, knocking other electrons out of their orbits. This condition exists throughout a wire when a current is flowing.

The propagation of free electrons is the tandem movement of free electrons as current flows.

DIRECTION OF CURRENT FLOW

Current flows from a negative charge which has an excess of electrons to a positive charge which has a defiency of electrons. Every time a path is provided, such as a wire, between two unequal charges, current will flow from negative to positive.

CONVENTIONAL THEORY OF CURRENT FLOW

The conventional theory of current flow was the original conception that current flows from positive to negative. Some publications, such as OP 821-A, still use the conventional theory. The conventional theory states that current flows from positive to negative outside the source, or external circuit, and negative to positive inside the source, or internal circuit.

To apply electron theory of current flow to publications and prints using the conventional theory of current flow, simply reverse the direction of current flow and leave all other information as it is.

ELECTRON THEORY OF CURRENT FLOW

The electron theory of current flow is the present conception that current flows from negative to positive. The electron theory is used in most publications and prints and will be used in all future publications and prints.

It was developed from the theory that current is electron flow, and electrons move from an excess to a deficiency or from negative to positive through an external circuit and from positive to negative through the source or internal circuit.

UNIT OF MEASURE

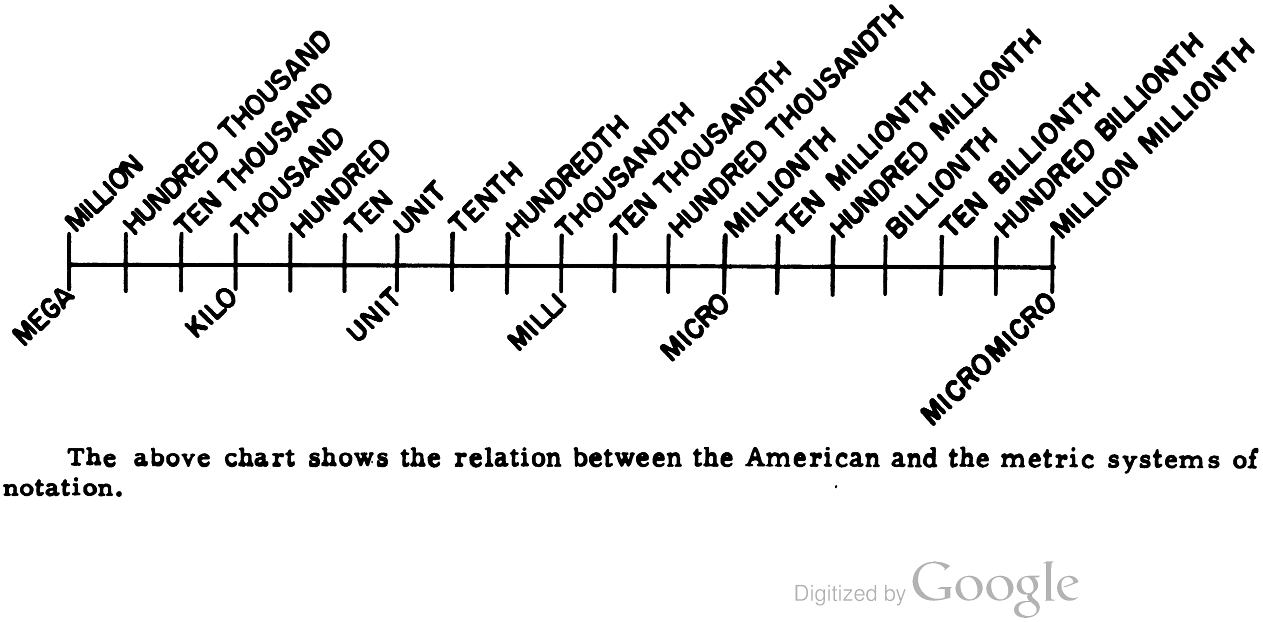
The electrical unit of volume is the coulomb. Current is the rate of flow, and the ampere is one coulomb per second. The ampere is seldom a practical unit of measure, so the milliampere or 1/1000 of one ampere is most used in fire control. Occasionally currents of less than one milliampere are found, and the microampere or 1/1,000,000 of one ampere is used as the unit of measure.

Amperes, milliamperes, and microamperes can be interchanged simply by moving the decimal point.

HOW CURRENT IS MEASURED

An ammeter measures current in amperes, a milliammeter in milliamperes, and a microammeter in microamperes. When the approximate value of current to be measured is not known, always use the largest scale available, to protect the meter. Always read a meter from a position that tends to minimize parallax and interpolate if needed for accurate readings.

METRIC RELATIONSHIPS



The above chart shows the relation between the American and the metric systems of notation.

METRIC CONVERSION TABLE

ORIGINAL VALUE	DESIRED VALUE					
	MEGA	KILO	UNITS	MILLI	MICRO	MICROMICRO
MEGA		3 →	6 →	9 →	12 →	18 →
KILO	← 3		3 →	6 →	9 →	15 →
UNITS	← 6	← 3		3 →	6 →	12 →
MILLI	← 9	← 6	← 3		3 →	9 →
MICRO	← 12	← 9	← 6	← 3		6 →
MICROMICRO	← 18	← 15	← 12	← 9	← 6	

The above metric conversion table provides a fast and automatic means of conversion from one metric notation to another. The notation "unit" represents the basic units of measurement, such as amperes, volts, ohms, watts, and cycles. To use the table, first locate the original or given value in the left-hand column. Now follow this line horizontally to the vertical column headed by the prefix of the desired value. The figure and arrow at this point indicate number of places and the direction decimal point is to be moved. Example: Convert 0.15 ampere to milliamperes. Starting at the "Units" box in the left-hand column (since ampere is the basic unit of measurement), move horizontally to the column headed by the prefix "Milli," and read 3 →. Thus 0.15 ampere is the equivalent of 150 milliamperes. Example: Convert 50,000 kilocycles to megacycles. Read in the box horizontal to "Kilo" and under "Mega" the notation ← 3, which means a shift of the decimal three places to the left. Thus 50,000 kilocycles is the equivalent of 50 megacycles.

JOB SHEET NO. 9

Fill in the following blanks. The metric conversion scale on Sheet II-4-4 may be used.

1. To convert milliamperes to amperes, move the decimal ___ places to the _________.
2. To convert microamperes to amperes, move the decimal ___ places to the _________.
3. To convert amperes to milliamperes, move the decimal _____ places to the ________.
4. To convert microamperes to milliamperes move the decimal _____ places to the _____.
5. .050 ampere equals _________ milliamperes.
6. 22,250 milliamperes equal _________ amperes.
7. 3.333 milliamperes equal _________ amperes.
8. 5.250 microamperes equal _________ amperes.
9. 750 milliamperes equal _________ amperes.
10. .0000005 ampere equals ______ microamperes.
11. In the electron theory of current flow, current flows from ______ to _________.

SECTION II

TOPIC 5

ELECTROMOTIVE FORCE

A. You have learned:

1. The scope of this course.
2. Introduction to Fire Control.
3. Introduction to Electricity.
4. About the Construction of Matter.
5. The Electron Theory.
6. How Electricity is Produced.
7. About Current Flow.

B. You are learning:

	References:
1. What Electromotive Force is.	NavPers 10622-B, page 43
2. What Potential and Potential Difference are.	NavPers 10622-B, pages 22 to 25; and 43 to 52
3. About Voltage and its Unit of Measure.	NavPers 10622-B, page 69
4. The Relation of Voltage to Current.	NavPers 10622-B, pages 22 to 25

C. You will acquire skill in:

1. Determining Potential Difference.
2. Converting Units of Voltage.

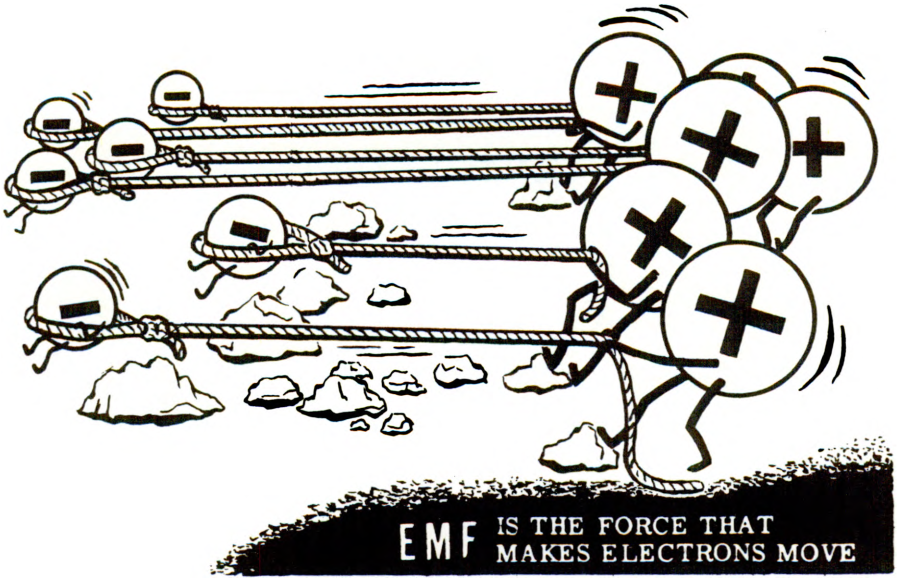
ELECTROMOTIVE FORCE

Current flow takes place whenever most of the electron movement in a material is in one direction. You have found out that this movement is from a minus charge to a plus charge and occurs only as long as a difference in charge exists.

To create a charge, electrons must be moved, either to cause an excess or a lack of electrons at the point where the charge is to exist.

A charge may be created by any of the six sources of electricity which you have studied about previously. These sources furnish the energy required to do the work of moving electrons to form a charge. Regardless of the kind of energy used to create a charge, it is changed to electrical energy once the charge is created; and the amount of electrical energy existing in the charge is exactly equal to the amount of the source energy required to create this charge.

When the current flows, the electrical energy of the charges is utilized to move electrons from less positive to more positive charges. The electrical energy is called electromotive force (emf) and is the moving force which causes current flow. Electrons may be moved to cause a charge by using energy from any of the six sources of electricity, primarily magnetism in fire control; but, when electrons move from one charge to another as current flows, the moving force is emf.



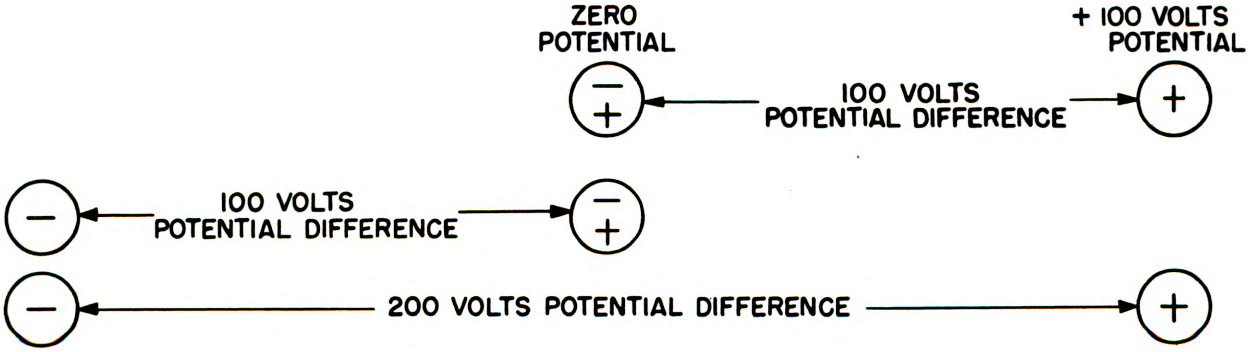
EMF IS THE FORCE THAT MAKES ELECTRONS MOVE

POTENTIAL AND POTENTIAL DIFFERENCE

An electric charge, whether positive or negative, represents a reserve of energy. This reserve energy is potential energy as long as it is not being used. The potential energy of a charge is equal to the amount of work done to create the charge, and the unit used to measure this work is the volt. The electromotive force of a charge is equal to the potential of the charge and is expressed in volts.

When two unequal charges exist, the electromotive force between the charges is equal to the difference in potential of the two charges. Since the potential of each charge is expressed in volts, the difference in potential is also expressed in volts. The difference in potential between two charges is the electromotive force acting between the charges--commonly called voltage.

Voltage, or a difference in potential, exists between any two charges which are not exactly equal. Even an uncharged body has a potential difference with respect to a charged body; it is positive with respect to a negative charge and negative with respect to a positive charge. Voltage exists, for example, between two unequal positive charges or between two unequal negative charges. Thus voltage is purely relative and is not used to express the actual amount of charge, but rather to compare one charge to another and indicate the electromotive force between the two charges being compared.

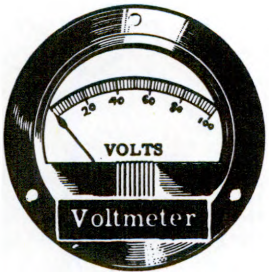

ZERO POTENTIAL
+ 100 VOLTS POTENTIAL
100 VOLTS POTENTIAL DIFFERENCE
100 VOLTS POTENTIAL DIFFERENCE
200 VOLTS POTENTIAL DIFFERENCE

VOLTAGE IS THE DIFFERENCE IN POTENTIAL

THE UNIT OF MEASURE OF VOLTAGE

The electromotive force between two unequal charges is usually expressed in volts, but when the difference in potential is only a fraction of a volt or is more than a thousand volts, other units are used. For voltages of less than one volt, millivolts and microvolts are used, just as milliamperes and microamperes are used to express currents less than one ampere. While current seldom exceeds one thousand amperes, voltage often exceeds one thousand volts, so that the killovolt--equal to one thousand volts--is used as the unit of measurement. When the potential difference between two charges is between one-thousandth of a volt and one volt, the unit of measure is the millivolt; when it is between one-millionth of a volt and one thousandth of a volt, the unit is the microvolt.

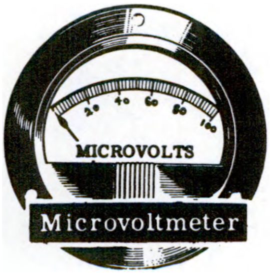
Meters for measuring voltage have scale ranges in microvolts, millivolts, volts and kilovolts, depending on the units of voltage to be measured. Ordinarily you will work with voltages between 1 and 500 volts and use the volt as a unit. Voltages of less than 1 volt and more than 500 volts are not used except in special applications of electrical equipment.



1 Volt = $\frac{1}{1000}$ Kilovolt

1 Volt = 1000 Millivolts

1 Volt = 1,000,000 Microvolts



1 Kilovolt = 1000 Volts

1 Millivolt = $\frac{1}{1000}$ Volt

1 Microvolt = $\frac{1}{1,000,000}$ Volt

In order to change millivolts to volts, the decimal point is moved three places to the left, and to change volts to millivolts the decimal point is moved three places to the right. Similarly, in changing microvolts to volts, the decimal point is moved six places to the left, and in changing volts to microvolts the decimal point is moved six places to the right.

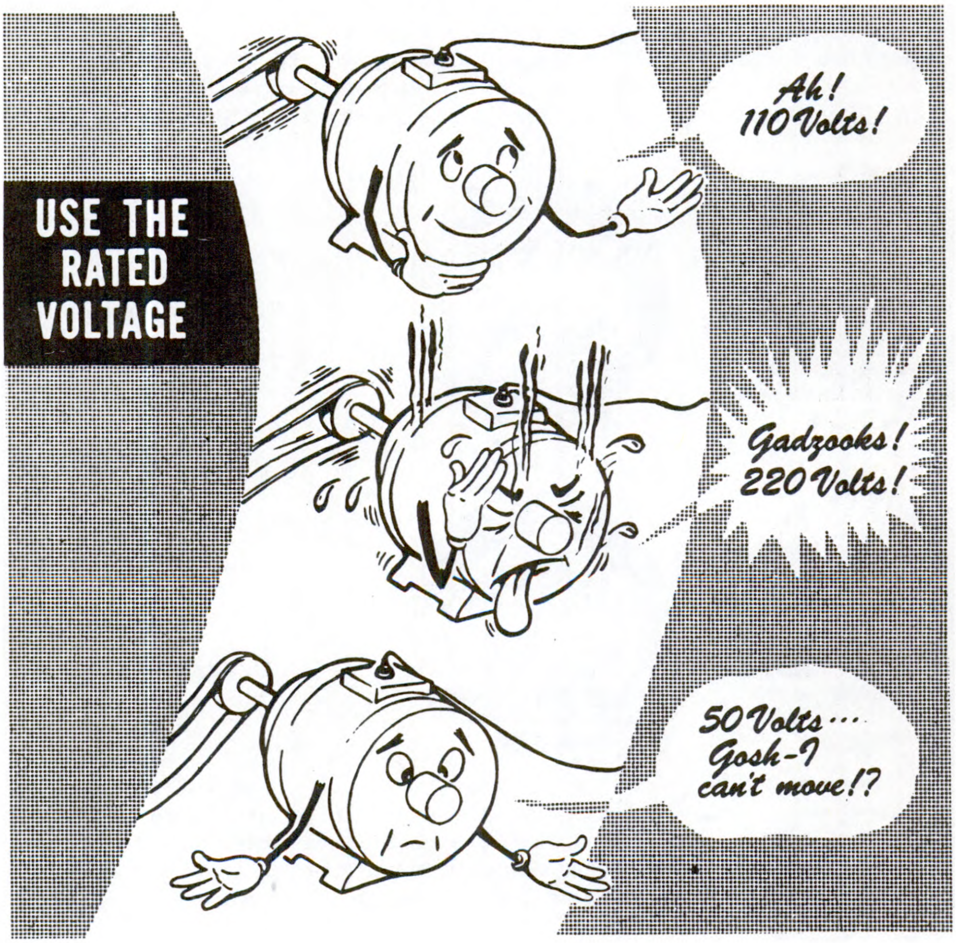
Kilo (meaning one thousand) is not used to express current, but since it is used to express voltage, you need to know how to change kilovolts to volts and the reverse. To change kilovolts to volts the decimal point is moved three places to the right, and to change volts to kilovolts, it is moved three places to the left. For example, 5 kilovolts equals 5,000 volts, since to the decimal point is after the 5. Three zeros are added to provide the necessary places. Also, 450 volts equals 0.45 kilovolt as the decimal point is moved three places to the left.

RELATION OF VOLTAGE TO CURRENT

Whenever two points of unequal charge are connected, a current flows from the more negative to the more positive charge. The greater the emf or voltage between the charges, the greater the amount of flow. Electrical equipment is designed to operate with a certain amount of current flow, and when this amount is exceeded, the equipment may be damaged.

You have seen all kinds of equipment, such as electric lamps, motors, and radios, with the voltage rating indicated. The voltage will differ on certain types of equipment, but it is usually 110 volts. This rating on a lamp, for example, means that 110 volts will cause the correct current flow. Using a higher voltage will result in a greater current flow and "burn out" the lamp, while a lower voltage will not cause enough current flow.

If a motor is designed to operate on 110 volts and you connect it to a 220-volt electric power line, the motor will be "burned out" due to excessive current flow; but the same motor placed across a 50-volt line will not operate properly because not enough current will flow. While current flow makes equipment work, it takes emf or voltage to cause the current to flow, and the value of the voltage determines how much current will flow.


USE THE RATED VOLTAGE
Ah! 110 Volts!
Gadzooks! 220 Volts!
50 Volts... Gosh-I can't move!?

JOB SHEET NO. 10

Fill in the following blanks:

1. Electromotive force is ______________________________

____

____

2. Potential is ______________________________

3. Potential Difference is ____

____

____

4. A ____________________ is used to measure voltage.

5. 4500 volts equal ____________ kilovolts.

6. .015 volt equals ____________ millivolts.

7. 65 volts equal ____________ microvolts.

8. 5 kilovolts equal ____________ volts.

9. 5000 millivolts equal __________ volts.

10. 3505 microvolts equal ________ volts.

11. Rated Voltage means ____

____

____

12. The most used source of obtaining voltage in fire control is ____________________

____________________.

SECTION II

TOPIC 6

RESISTANCE

A. You have learned:	References:
1. The scope of this course.	
2. Introduction to Fire Control.	
3. Introduction to Electricity.	
4. About the Construction of Matter.	
5. The Electron Theory.	
6. How Electricity is Produced.	
7. About Current Flow.	
8. About Electromotive Force.	
B. You are learning:	
1. What Resistance is.	NavPers 10622-B, pages 20 and 21
2. About Conductors and Insulators.	NavPers 10622-B, pages 20 to 26
3. About Resistive Devices and Ratings.	NavPers 10170-B, pages 17 to 32
4. The Unit of Measure of Resistance.	NavPers 10622-B, page 69
C. You will acquire skill in:	
1. Converting Units of Resistance.	
2. Color Coding Resistors.	

WHAT RESISTANCE IS

Resistance is opposition to current flow, and depends on the number of free electrons in a material. It is actually opposition to the movement of free electrons.

Opposition to current is not the same in all materials. Materials having many free electrons offer little opposition to current flow, and they are low-resistance materials. Other materials have few free electrons, and they offer high resistance to current flow. Every material has some opposition to current flow, whether large or small, and this opposition is called resistance. There is something in a material that resists the flow of electric current--something that holds on to the "free" electrons and will not release them until sufficient force is applied.

There are four factors that govern resistance. Every type of material has a different attraction or hold on its free electrons, and, therefore, has a different resistance. Increasing the length of a material increases its resistance, because current has to be forced through a longer path. Increasing the cross section of a material decreases its resistance, and decreasing the cross section increases its resistance, because the larger the cross section the more free electrons there are available. Increasing the temperature changes the ease with which that material releases its outer electrons.

With a constant amount of electrical force (voltage), the more opposition you have to current flow (resistance), the smaller will be the number of electrons flowing through the material (current). Using the same source of voltage, the lower the resistance, the greater the current. Thus, if you have a fixed source of voltage, you can increase the current by decreasing the resistance. You can also decrease the current by increasing the resistance. By increasing or decreasing the amount of resistance--opposition to electron movement--in a circuit, you can adjust the amount of current flow to meet the operating needs of electrical and electronic fire control equipment.

CONDUCTORS AND INSULATORS

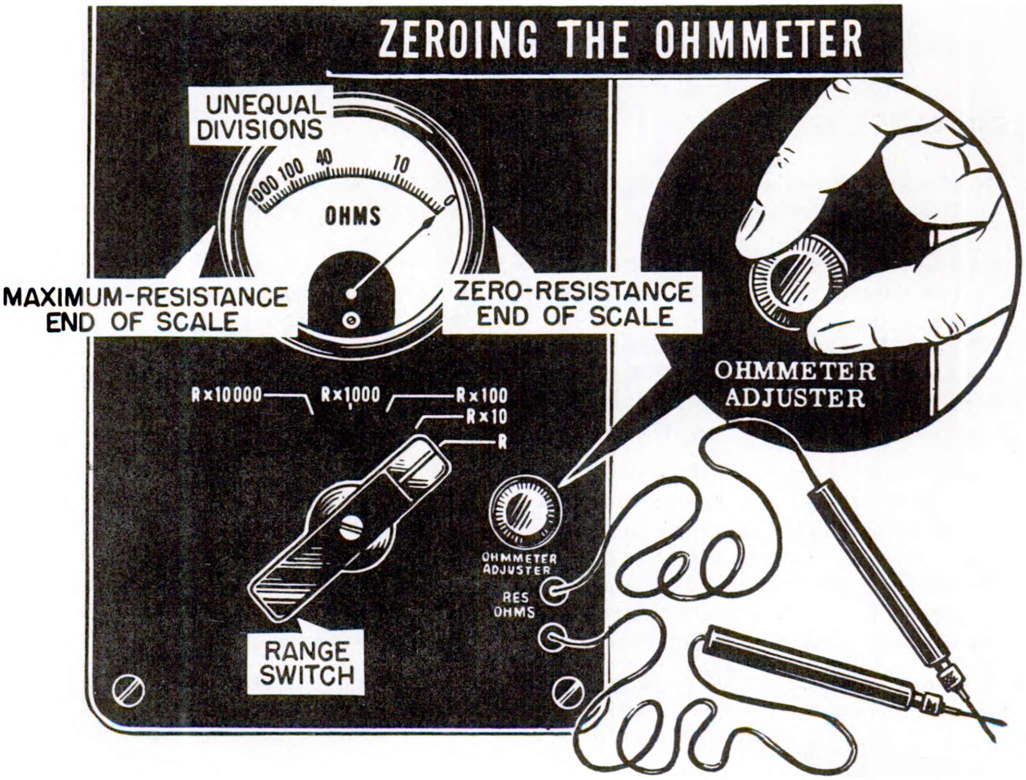
A conductor offers very little opposition to current flow; in other words, has such a small resistance it can be considered as zero in most cases. Conductors are used to carry or conduct current. Metals are among the best conductors--gold, silver, mercury, copper, aluminum, and iron being used in many types of Fire Control equipment. Carbon and water are examples of non metalic conductors. Salt water is an unwanted conductor and has to be guarded against constantly by all Fire Control Technicians at sea.

"Insulators" offer very great opposition to current flow or infinite resistance, and current flow through an insulator can be considered zero. Insulators have few free electrons and are used to block or insulate the flow of current. Materials such as glass, paper, rubber, ceramics, and certain plastics are commonly used as insulators.

UNIT OF MEASURE OF RESISTANCE

The basic unit of resistance is the "ohm" (Ω), which is the resistance that will allow one ampere to flow when one volt is applied.

You will use resistance values which can be expressed in ohms (Ω), thousands of ohms expressed in kilohms (K̲), millions of ohms expressed in megohms (M̲), and for certain special applications you may use small values of less than one ohm, or millionths of one ohm, which is expressed in microhms (μΩ).



Units of resistance are changed in the same manner as units of current or voltage. To change microhms to ohms the decimal point is moved six places to the left, and to change ohms to microhms the decimal point is moved six places to the right. To change megohms to ohms the decimal point is moved six places to the right, and to change ohms to megohms it is moved six places to the left. To change kilohms to ohms the decimal point is moved three places to the right, and to change ohms to kilohms the decimal point is moved three places to the left.

Meters used to measure resistance are called ohmmeters. They have unequal scale divisions and a built-in battery. NO POWER should be on when using an ohmmeter, or it may be damaged beyond repair. Ohmmeter ranges vary from zero (0) to infinity(∞), and the accuracy of the meter decreases at the ends of the scale. Unlike other meters, the zero end of the ohmmeter scale is at full-scale deflection of the meter pointer.

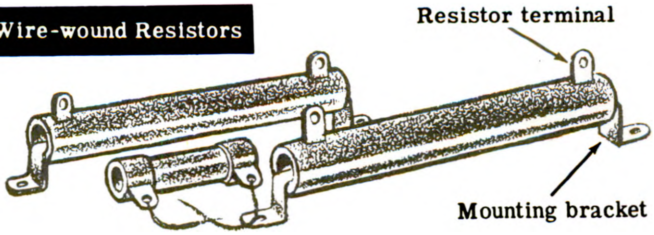
Before using an ohmmeter, select the proper range and short the test prods. Then set the ohmmeter adjuster control to obtain exactly full-scale deflection--zero ohms on the meter scale.

RESISTIVE DEVICES AND RATINGS

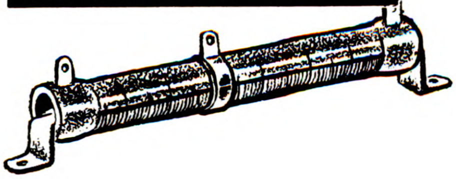
Devices used to introduce resistance in a circuit are called "resistors." Fixed resistors have a fixed value and come in many shapes, forms, and sizes.

You will use a wide variety or resistors, some of which have a fixed value and others are adjustable or variable. Adjustable resistors come in several forms and may have their resistance changed when power is removed. Variable resistors may have their resistance changed while in operation. All resistors are made either of special resistance wire, of graphite (carbon) composition, or metal film. Wire-wound resistors are usually used to control large currents or develop accurate voltages, and may be hollow to dissipate large amounts of heat so that they won't burn out.

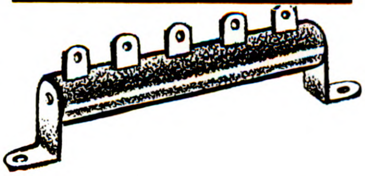
Fixed Wire-wound Resistors



Adjustable Wire-wound Resistors

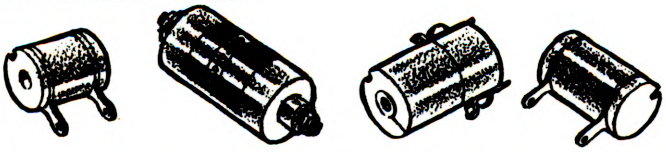


Wire-wound Resistor With Fixed Taps

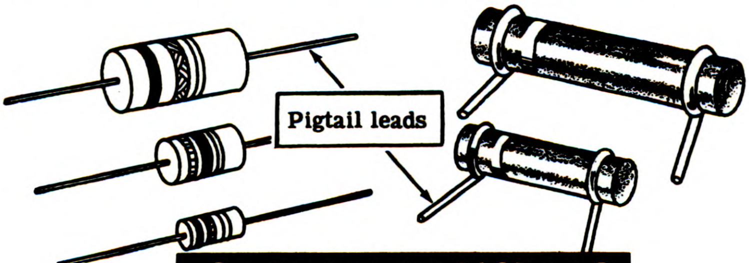


Wire-wound resistors may have fixed taps which can be used to change the resistance value in steps, or sliders which can be adjusted to change the resistance to any fraction of the total resistance.

Precision Wire-wound Resistors

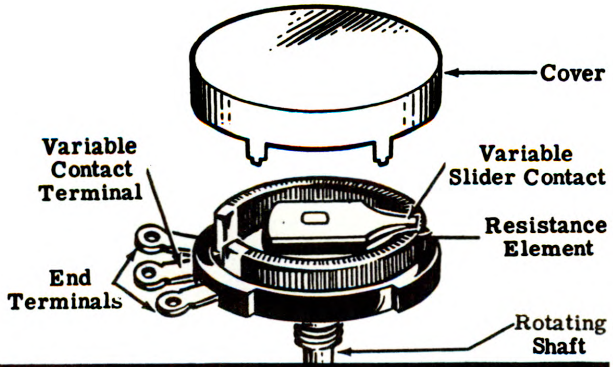


Precision wound resistors of Manganin wire are used where the resistance value must be very accurate such as in test instruments and computers.

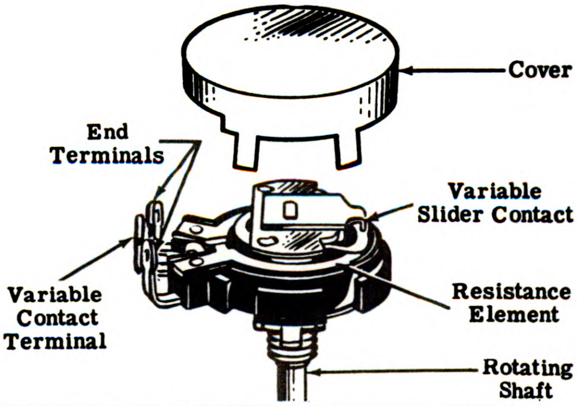


CARBON RESISTORS

Metal film resistors are seldom used in fire control equipment, therefore an explanation will not be given here. Carbon resistors control relatively small currents or develop voltages of relatively low tolerance.



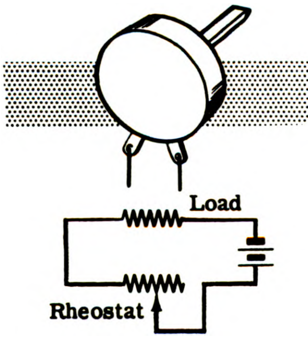
WIRE-WOUND VARIABLE RESISTORS



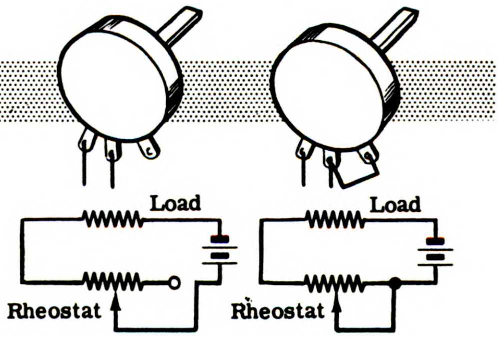
CARBON VARIABLE RESISTORS

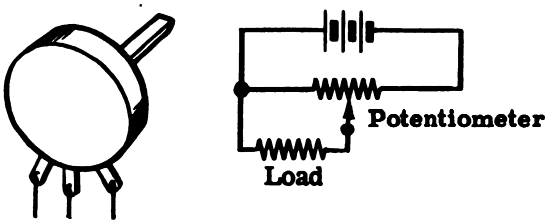
Variable resistors may be connected as rheostats or potentiometers. Rheostats control current and only two terminals are used. Potentiometers control voltage and all three terminals are used.

TWO-TERMINAL VARIABLE RESISTORS



THREE-TERMINAL VARIABLE RESISTORS

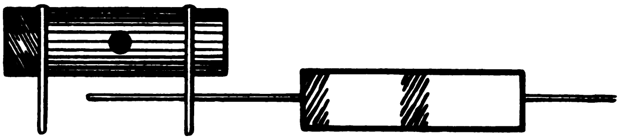




POTENTIOMETER CONNECTIONS

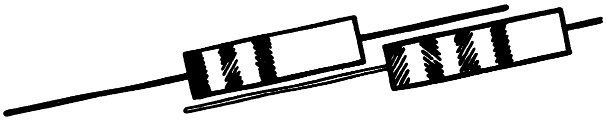
This is how you use the color code--

Color	Number	Tolerance	Color	Number	Tolerance
Black	0	-	Violet	7	7%
Brown	1	1%	Gray	8	8%
Red	2	2%	White	9	9%
Orange	3	3%	Gold	-	5%
Yellow	4	4%	Silver	-	10%
Green	5	5%	No Color	-	20%
Blue	6	6%			



Body-End-Dot Marking

Resistors using this system of marking are coded by having the body of the resistor a solid color, one end of another color, and a dot of a third color near the middle of the resistor. For example, you may have a resistor with a green body, red end, and orange dot. The body color indicates the first digit, the end color the second digit, and the dot the number of zeros to be added to the digits.



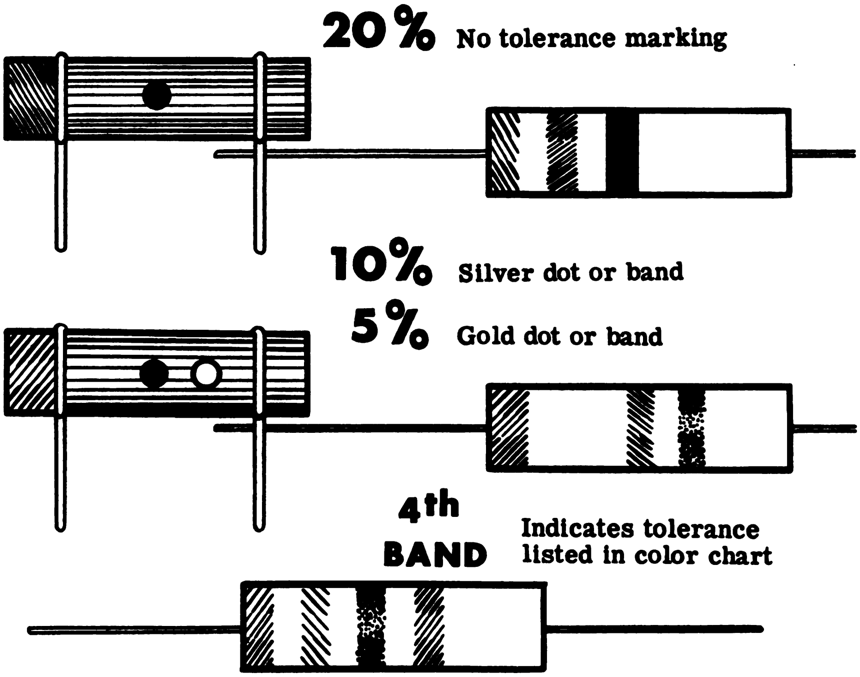
End-to-Center Band Marking

Axial resistors are usually marked with bands of color at one end of the resistor. The body color is not used to indicate the resistor value and may be any color that is not identical to any of the bands. For example, you may have a resistor with a brown body, having three bands of color (red, green, and yellow) at one end. The color bands are read from the end toward the center and the resistor value is 250,000 ohms, obtained as follows:

1st Band	2nd Band	3rd Band
1st digit	2nd digit	Number of zeros
Red	Green	Yellow
2	5	0000

250,000 ohms

Tolerance denotes a resistor's accuracy and is indicated by a fourth color or no fourth color as follows:



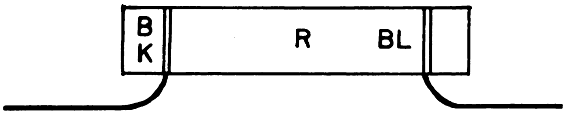
RESISTOR TOLERANCE MARKINGS

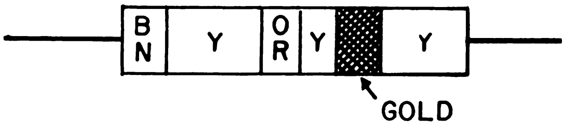
JOB SHEET NO. 11

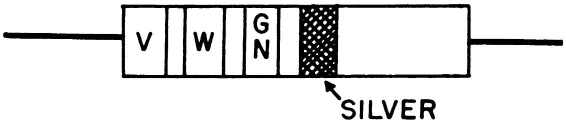
Fill in the following blanks:

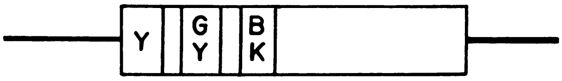
1. Resistance is ____
   ____
2. An ______________________ is used to measure resistance.
3. __________ is the symbol for microhms.
4. The decimal point is moved _______ places to the _________ to change ohms to kilohms.
5. Rheostats control _________ and potentiometers control _______________.

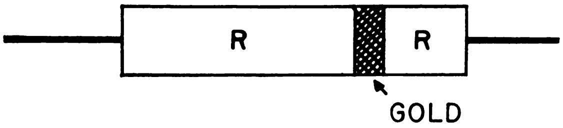
What is the resistance and tolerance of the following:











SECTION III

ELECTRICAL CIRCUITS, D-C

Topic No.	Topic Title	Sheet
1.	Introduction To D-C Circuits	III-1-1
2.	What a Circuit Is	III-2-1
3.	D-C Series Circuit	III-3-1
4.	Ohm's Law--Series Circuit	III-4-1
5.	Electrical Power	III-5-1
6.	D-C Parallel Circuit.	III-6-1
7.	Ohm's Law--Parallel Circuit	III-7-1
8.	D-C Series--Parallel Circuits	III-8-1
9.	Kirchhoff's Laws	III-9-1

SECTION III

TOPIC 1

INTRODUCTION TO D-C CIRCUITS

A. You have learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
B. You are learning:	
1. Contents of D-C circuits.	NavPers 10170, Vol. I, 10171, Vol. II, pages 1-14

WHAT A CIRCUIT IS

A complete circuit must contain a source of voltage, a path or conductor from the source to the load and from the load back to the source, and a load which uses the energy supplied by the source. In a circuit, the current flows from the negative (-) terminal of the source through the path, through the load, through a return path to the positive (+) terminal of the source, and through the source back to the negative terminal of the source. This is a very simple circuit, but the most complex circuits are made up of several very simple circuits.

D-C SERIES CIRCUIT

A series circuit is one in which there is only one path for current flow similar to the one just described. There may be several different components that make up the load, but they are connected in tandem so that the current flow through all parts of the circuit is the same. The sum of all the voltages (voltage drops) across the individual components equals the source (total) voltage.

OHM'S LAW

Voltage, current, and resistance have a definite relationship to one another. When voltage is constant and resistance is changed, the current change will be inversely proportional. When resistance is constant and voltage is changed, the current change will be directly proportional. To keep current constant as resistance is changed, the voltage across the component will have to be changed proportionally.

The formula for Ohm's Law is:

Voltage is equal to current times resistance, or E equals IR.

This formula may be transposed to find values of current or voltage.

ELECTRICAL POWER

When force causes motion, work is done. Power is the rate of doing work whether it is mechanical or electrical. Electrical power is measured in watts and is equal to current times voltage, or P equals IE.

Ohm's Law may be substituted in the power formula to obtain P equals I2R and P equals E^2R.

All electrical equipment has a power rating. This equipment should never use more than its rated power, or it will be damaged.

D-C PARALLEL CIRCUITS

Electrical devices connected side by side are parallel connected. Electrical cells or generators connected positive to positive and negative to negative are also parallel connected.

Equipment that is connected in parallel across the power line must have similar voltage ratings.

Parallel-connected resistances increase the cross-sectional area of the total circuit, hence cause the resistance of the total circuit to be less than that of the smallest single resistance. The total resistance of equal resistances connected in parallel equals the value of one resistance divided by the number of resistances. The total resistance of two unequal resistances connected in parallel is found by dividing the product of the two resistances by their sum. The mathematical equation is $R_T = R_1 x R_2/R_1$ plus R_2.

The total current in a parallel circuit is equal to the sum of the currents in the individual branches.

The voltage across all branches of a parallel circuit is equal, and is also equal to the total voltage.

OHM'S LAW IN PARALLEL CIRCUITS

Using Ohm's Law eliminates the need to measure individual values. To find resistance of any branch, use values of voltage and current in that branch. To find total resistance, use only total values of current and voltage.

Values of current may be found in any branch if resistance and voltage in that branch are known. Total current is found by using values of total resistance and voltage.

Total voltage is found by using total values of resistance and current which is the same voltage found by using individual values of resistance and current.

D-C SERIES--PARALLEL CIRCUITS

Series-parallel circuits contain both series and parallel-connected devices, and can be simplified to a single equivalent resistance by using the formulas for series and parallel circuits.

KIRCHHOFF'S LAWS

Kirchhoff's current law states that the current entering a junction must equal the current leaving the junction and is used to determine unknown currents in a circuit.

Kirchhoff's voltage law states that the sum of the voltage drops around a circuit equals the voltage applied to the circuit and is used to determine unknown voltages in a circuit.

SECTION III

TOPIC 2

WHAT A CIRCUIT IS

A. You have learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
3. The contents of d-c circuits.	
B. You are learning:	
1. About circuits in general.	NavPers 10622-B, pages 27 to 54; 54 to 64

WHAT A CIRCUIT IS

A complete circuit is an unbroken path through which current flows from the negative terminal of the source to the load, back to the positive terminal of the source, and from positive to negative through the source. Direct current circuits consist of a source of d-c voltage, plus the combined resistance of the electrical equipment connected across this voltage. The total resistance of the circuit will control the current flowing through the circuit.

The source is the generator, battery, or any other unit that supplies the electrical energy. The path is the wire or conductor that allows current flow from the source to the load, and from the load back to the source. The load is the equipment that is connected to the source and may vary from a simple resistor to more complicated equipment such as Power Drive Mk 4.

There are three general types of circuits. A series circuit is one in which there is only one path for current to flow. A parallel circuit is one in which there is more than one path for current flow. A series-parallel circuit is a combination of series and parallel circuits.

Sometimes a circuit having only one load connected to a source is called a simple circuit. There are very few simple circuits in actual use.

A few of the electrical symbols are as follows:

1. Voltage (E) is measured in volts (V).
2. Current (I) is measured in amperes (A).
3. Resistance (R) is measured in ohms (Ω).
4. Power (P) is measured in watts (W).

You will find many other symbols as you advance in study, but they will be as simple as the eight symbols you have just covered.

Circuit faults are anything that causes the circuit to OPEN, GROUND, or SHORT; or partially open, ground, or short. The effect of these faults is to change current and voltage values so that the equipment does not operate correctly, and frequently does not operate at all. Sometimes--not often--faults are unavoidable. In your circuits, make sure that your circuit faults are not your fault.

Open circuits may result from dirty or loose connections, careless runs of cable, mechanical damage, faulty installation or repair, and many other causes common to shipboard use, such as vibration. Good connections are clean and tight, and no resistance is added to the circuit.

Short circuits are low-resistance paths or ''shortcuts'' that cause the current to bypass the load. The current from the source passes through the ''short'' instead of the load, causing the load to not operate properly. Most shorts are accidental. They occur when vibration wears away insulation, when salt water gets into connection boxes, when heat melts away insulation, and when carelessness brings two conductors together.

A grounded circuit is one in which one side of the path is connected to ground either intentionally or accidentally. An intentionally grounded circuit uses ground which is the ship's hull, equipment chassis, etc., as one side of the line or one conductor. If the hot side of a grounded conductor touches ground accidentally, a short circuit is the result. Power circuits in the Navy are not grounded and must be insulated from ground at all times. One side of this circuit may be grounded accidentally, and no harm will result, but, if both sides are grounded, a short circuit is the result. An ungrounded circuit has a safety feature. If an FT accidentally touches one side of the line, there will be no path for current flow through his body to the other side of the source. Now you can see one reason why power circuits are insulated from ground.

JOB SHEET NO. 12

Fill in the following blanks and answer questions as applicable.

1. A complete circuit is

____

____

____

____

____

____

____

____

2. A load is

____

____

3. Name the three types of circuits: a. ____________________

b. ____________________ c. ____________________

4. Fill in the applicable symbols.

a. Resistance ______ b. Ohms ______

c. Voltage ______ d. Volts ______

e. Current ______ f. Amperes ______

g. Power ______ h. Watts ______

5. State several causes for the following circuit faults:

a. Open circuit (1) ______

(2) ______ (3) ______

(4) ______ (5) ______

b. Short circuit (1) ______

(2) ______ (3) ______

(4) ______ (5) ______

c. Grounded circuit (1) ______

(2) ______ (3) ______

(4) ______ (5) ______

6. How would equipment be affected if one side of its ungrounded power circuit accidentally became grounded?

______

______

______

7. What would happen to YOU if you accidentally connected your body between the hot side of a grounded circuit and ground, and why?

______

______

______

______

8. What would happen to YOU if you accidentally connected your body between the grounded side of a grounded circuit and ground, and why?

______

______

______

SECTION III

TOPIC 3

D-C SERIES CIRCUITS

A. You have learned:

1. About Fire Control in general.
2. About electricity fundamentals.
3. The contents of d-c circuits.

B. You are learning about:	References:
1. How series circuits are connected	NavPers 10622-B, pages 71 to 72
2. About resistance in a series circuit	NavPers 10622-B, pages 76 to 78
3. About current in a series circuit	NavPers 10622-B, pages 75 to 76
4. About voltage in a series circuit	NavPers 10622-B, pages 72 to 75

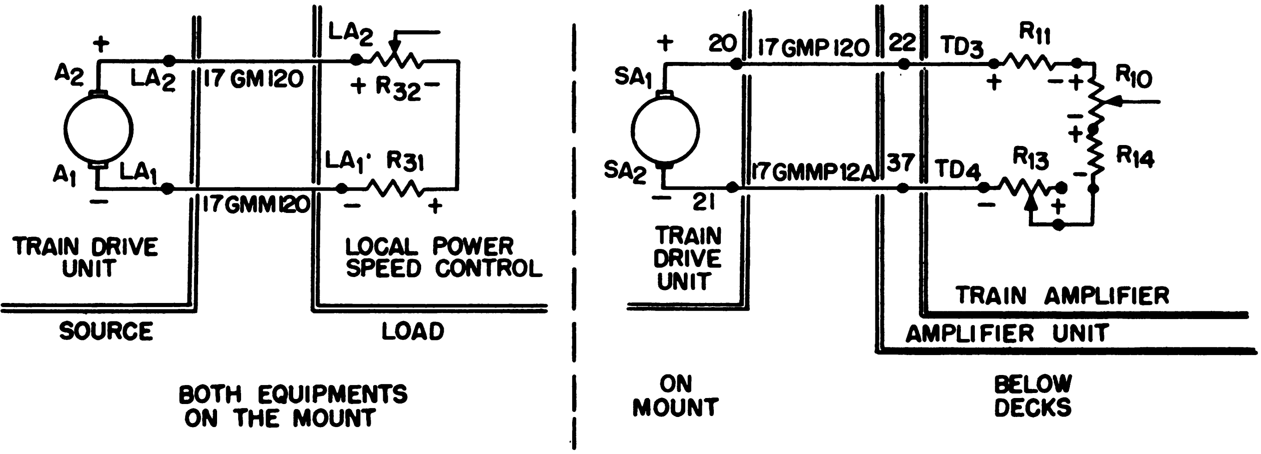
C. You will acquire skill in:

1. Solving basic d-c series problems.

SERIES CIRCUIT CONNECTIONS

Resistors or other electrical devices are connected end to end, or in tandem when connected in series. The devices are connected negative to positive throughout the circuit, and the negative side of the line is connected to the negative side of source. The positive side of the line is connected to the positive side of the source. There is only one path for current flow from the negative to the positive side of the source.

These series-connected devices may be in instruments or equipments in separate parts of the ship; therefore, they will be connected by conductors. There are several series circuits in Power Drive Mk 4 where part of the circuit is on the gun mount, and the remainder of the circuit is in the below-decks mounted equipment.



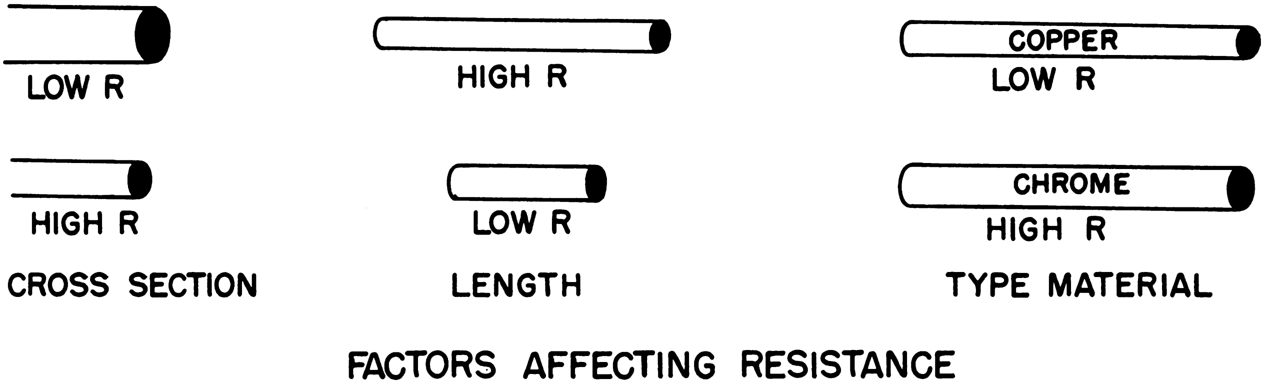
RESISTORS IN SERIES

RESISTORS IN SERIES

The total resistance of electrical devices connected in series equals the sum of the individual resistances.

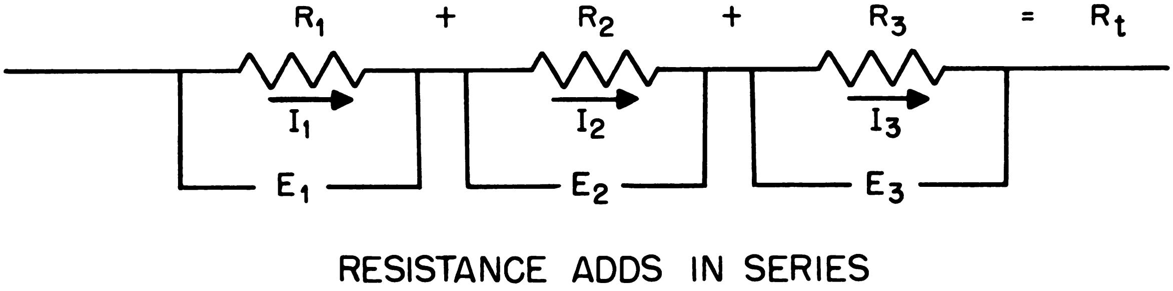
Increasing the length of resistance material or of a conductor will increase its resistance. Decreasing the length of any material will decrease its resistance.

Increasing the cross section of a material decreases its resistance, while decreasing the cross section increases its resistance. The type of material with which a conductor or resistor is made is the third factor in determining its resistance.



FACTORS AFFECTING RESISTANCE

When there is more than one device in a circuit, subscripts are used to identify or separate the devices. Numbers or letters are also used to identify circuit devices.



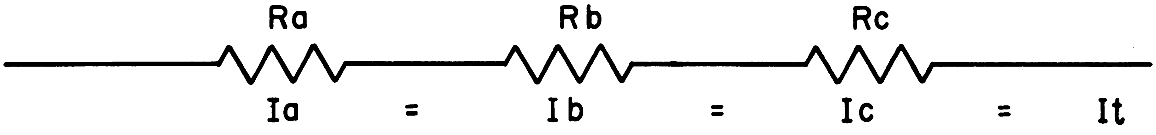
RESISTANCE ADDS IN SERIES

CURRENT IN SERIES

The current flow is equal through all parts of a series circuit, because there is only one path for current to flow. This means that all the current must flow through each resistor regardless of value, and the current through all resistors will be the same regardless of value.

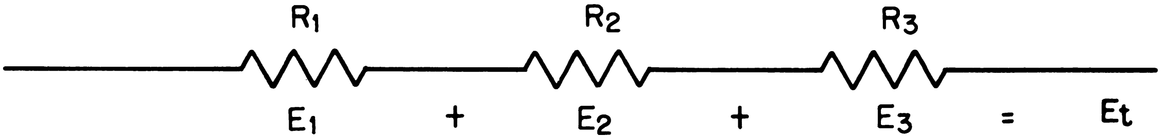
Remember, all parts of the circuit must be able to pass the maximum current which flows, and the total resistance of the circuit must be large enough to reduce the amount of current to a value which can be safely passed by all the current resistances. If too much current flows through the circuit, one or more of the components may be damaged.

The components of all parts of a series circuit must have the same current rating because the same value of current is flowing through all parts.



VOLTAGE IN SERIES

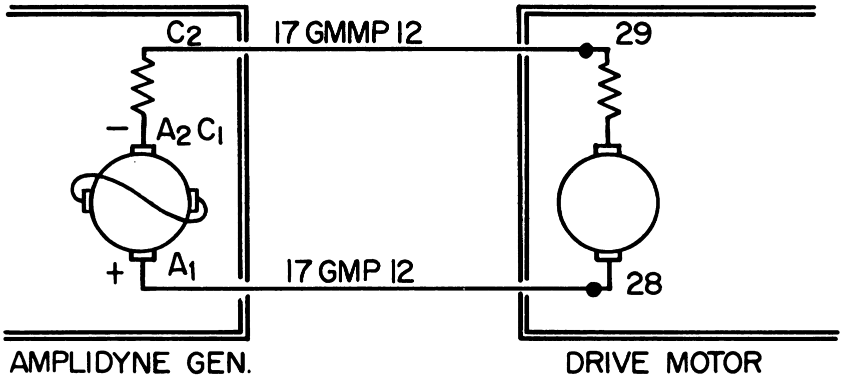
The voltage divides in a series circuit in proportion to the resistance of each part of the circuit. The sum of the voltage drops across the separate resistances is always equal to the applied voltage. The voltage drop is the emf that is exerted when the current is forced through that resistance. If all resistances in a series circuit are equal, the voltage drops are equal, because current is the same throughout the circuit.



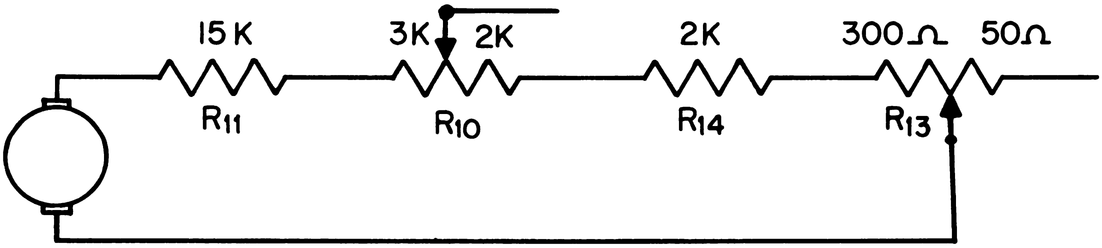
JOB SHEET NO. 13

Fill in the answers and solve the following problems:

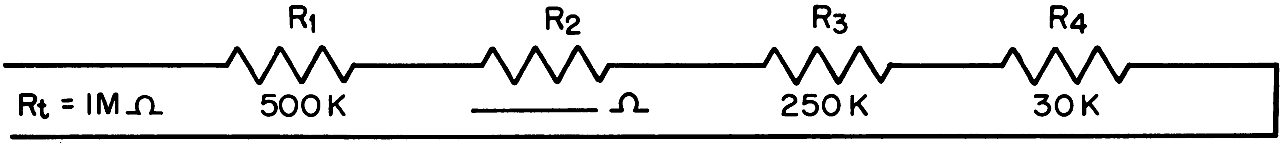
1. Polarize this series circuit. ______________________________



2. What is R_t offered to the generator? ______________________________



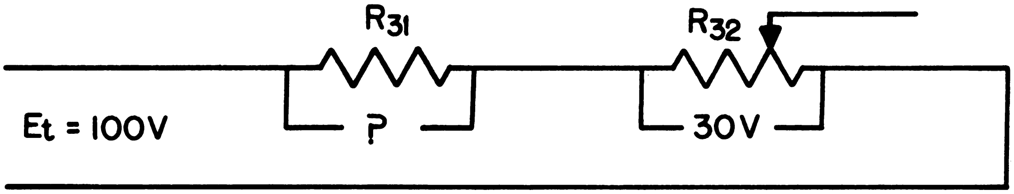
3. What is the value of R_2? ______________________________



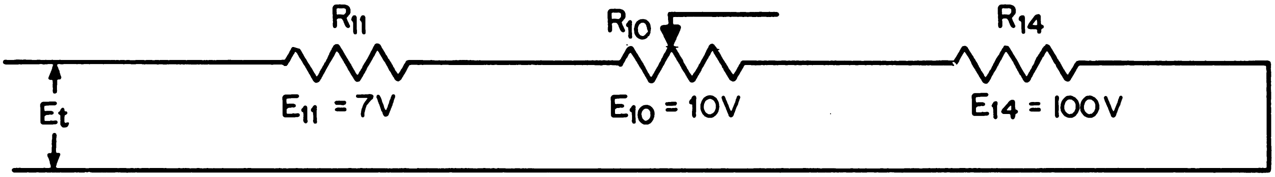
4. **In Problem No. 2, current through R_{11} is 1 ma. What is the current through R_{14}?**

5. **In Problem No. 3, current through R_1 is 56 ma. What is the current through R_3?**

6. **What is the voltage drop across R_{31}?**



7. **What is E_t ?**



SECTION III

TOPIC 4

OHM'S LAW--SERIES CIRCUIT

A. You Have Learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
3. The contents of d-c circuits.	
4. The basic characteristics of d-c series circuits.	
B. You Are Learning:	
1. What Ohm's Law is.	NavPers 10622-B, pages 55-56
2. The mathematical expression of Ohm's Law.	NavPers 10622-B, pages 56-59
3. The uses of Ohm's Law.	NavPers 10622-B, pages 56-59
C. You Will Acquire Skill In:	
1. Applying Ohm's Law in d-c series circuits.	

OHM'S LAW

During the late 1700's and early 1800's, three great electrical discoveries were made. An Italian, named Volta, discovered how to produce an emf from a primary cell. He gave his name to the measuring unit of electromotive force--the VOLT. Ampere, a Frenchman, measured current flow and gave his name to the measuring unit of current--the AMPERE. A German, named Ohm, measured the resistance of circuits and conductors and gave his name to the resistance measuring unit--the OHM. Ohm did more than experiment with resistance--he connected his discoveries with those of Volta and Ampere.

Ohm found that if he held the resistance of a circuit at a fixed value and increased the voltage to the circuit, the current would increase proportionally. Likewise, when he decreased the voltage, with the resistance fixed, the current would decrease proportionally. Thus, in a circuit with fixed resistance, if the voltage was low the current would be low, and if the voltage was high the current would be high.

Ohm made another important discovery. He found that if he held the voltage to a circuit at a fixed value and increased the resistance of the circuit, the current would decrease proportionally. Likewise, when he decreased the resistance, with the voltage fixed, the current would increase proportionally. Thus, in a circuit with a constant voltage, if the resistance was low the current would be high, and if the resistance was high the current would be low.

Combined, these two discoveries show that the amount of current in a circuit depends upon the amount of electrical pressure, or voltage, and the amount of resistance.

This fact is expressed by Ohm's Law, and is the fundamental equation of all electrical science. One of the most common ways of expressing Ohm's Law is that

> THE CURRENT FLOWING IN A CIRCUIT IS DIRECTLY PROPORTIONAL TO THE APPLIED VOLTAGE, AND INVERSELY PROPORTIONAL TO THE RESISTANCE.

Ohm's Law is used in electrical circuits and parts of circuits to find the unknown quantity of current, voltage, or resistance when any of these quantities are known.

MATHEMATICAL EXPRESSION OF OHM'S LAW

In order to make use of Ohm's Law the word statement must be converted to a mathematical expression. Thus the word statement of Ohm's law, when expressed mathematically is

$$\text{CURRENT} = \frac{\text{ELECTROMOTIVE FORCE (or VOLTAGE)}}{\text{RESISTANCE}}$$

or $$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

or $$I = \frac{E}{R}$$

Ohm's Law can also be written in two other forms.

$$\text{VOLTAGE} = \text{CURRENT} \times \text{RESISTANCE}$$

or $$\text{VOLTS} = \text{AMPERES} \times \text{OHMS}$$

or $$E = IR$$

This enables you to find the voltage when you know current and resistance.

If you know the voltage and the current, you can find the resistance by simply applying the following form of Ohm's Law.

$$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

or $$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

or $$R = \frac{E}{I}$$

Thus you can see that Ohm's Law may be mathematically expressed by three equations. From your knowledge of mathematics, you recognize that these three equations are variations of one formula.

$$I = \frac{E}{R},\ E = IR,\ \text{and } R = \frac{E}{I}$$

If you know any two of these quantities in a circuit, or in any part of a circuit, you can calculate the other quantity by applying the proper equation.

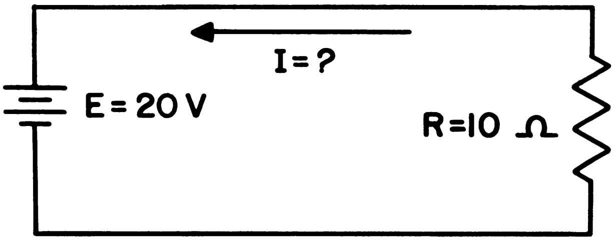
USE OF OHM'S LAW

Now that you know what Ohm's Law is, the next problem is how to use it, to find the current through a resistance. As you know, the current in a circuit increases if the voltage increases and the resistance remains the same. By giving values to E and R, you can see how this works. Suppose that R is 10 ohms and E is 20 volts. Since the current equals 20 divided by 10, the current is 2 amperes.

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}}$$

$$I = \frac{E}{R}$$

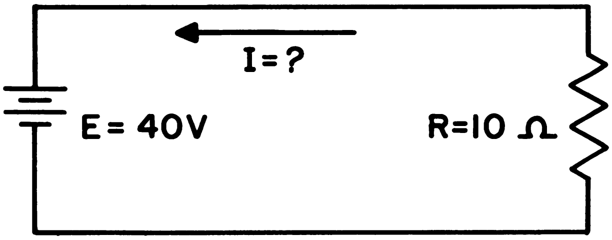
$$I = \frac{20}{10} = 2 \text{ AMPERES}$$



Now if E is increased to 40 volts without changing the resistance, the current increases to 4 amperes.

$$I = \frac{E}{R}$$

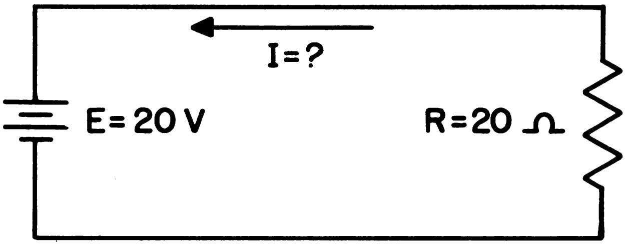
$$I = \frac{40}{10} = 4 \text{ AMPERES}$$



Similarly, if the voltage remains the same and the resistance is increased, the current decreases. Using the original values where E is 20 volts and R is 10 ohms, you found that the current is 2 amperes. If R is increased to 20 ohms without changing the voltage, the current decreases to 1 ampere.

$$I = \frac{E}{R}$$

$$I = \frac{20}{20} = 1 \text{ AMPERE}$$

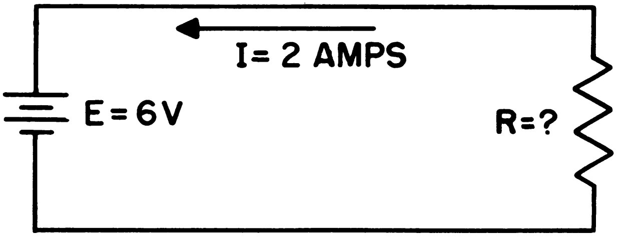


While $I = \frac{E}{R}$ is the basic form of Ohm's Law and is used to find current, by expressing the law in other forms, it may be used to obtain either E or R. To use Ohm's Law to find the resistance when voltage and current are known, the voltage is divided by the current. As an example, if the current through a circuit is 2 amperes and the applied voltage is 6 volts, the resistance of the circuit is 3 ohms.

$$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

$$R = \frac{E}{I}$$

$$R = \frac{6}{2} = 3 \text{ OHMS}$$

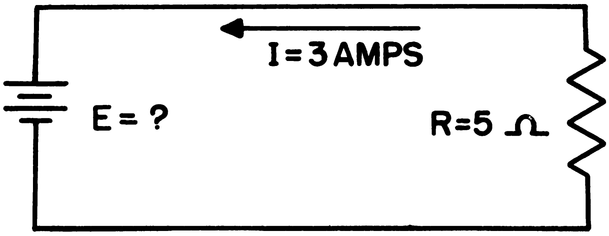


A third use of Ohm's Law is to find the voltage when the current and resistance are known. To find the voltage across a resistance, the current is multiplied by the resistance. To find the voltage across a 5-ohm resistor when 3 amperes of current are flowing, you must multiply I times R, so that the voltage equals 15 volts.

VOLTAGE = CURRENT x RESISTANCE

$\underline{E} = \underline{IR}$

$E = 3 \times 5 = 15$ VOLTS



In using Ohm's Law, the quantities must always be expressed in the basic units of current, voltage, and resistance. If a quantity is given in larger or smaller units, it must first be changed so that it is expressed in amperes, volts, or ohms.

APPLYING OHM'S LAW TO A SERIES CIRCUIT

In order to apply Ohm's Law to a series circuit you will have to remember three important characteristics of a series circuit:

1. The total resistance (R_t) in a series circuit is equal to the sum of the individual resistances in that circuit. $R_t = R_1$ plus R_2 plus R_3, etc.

2. The sum of the voltage drops in a series circuit is equal to the total impressed voltage (E_t). $E_t = E_1$ plus E_2 plus E_3, etc.

3. The current flowing in a series circuit is everywhere the same. $I_t = I_1 = I_2 = I_3$, etc.

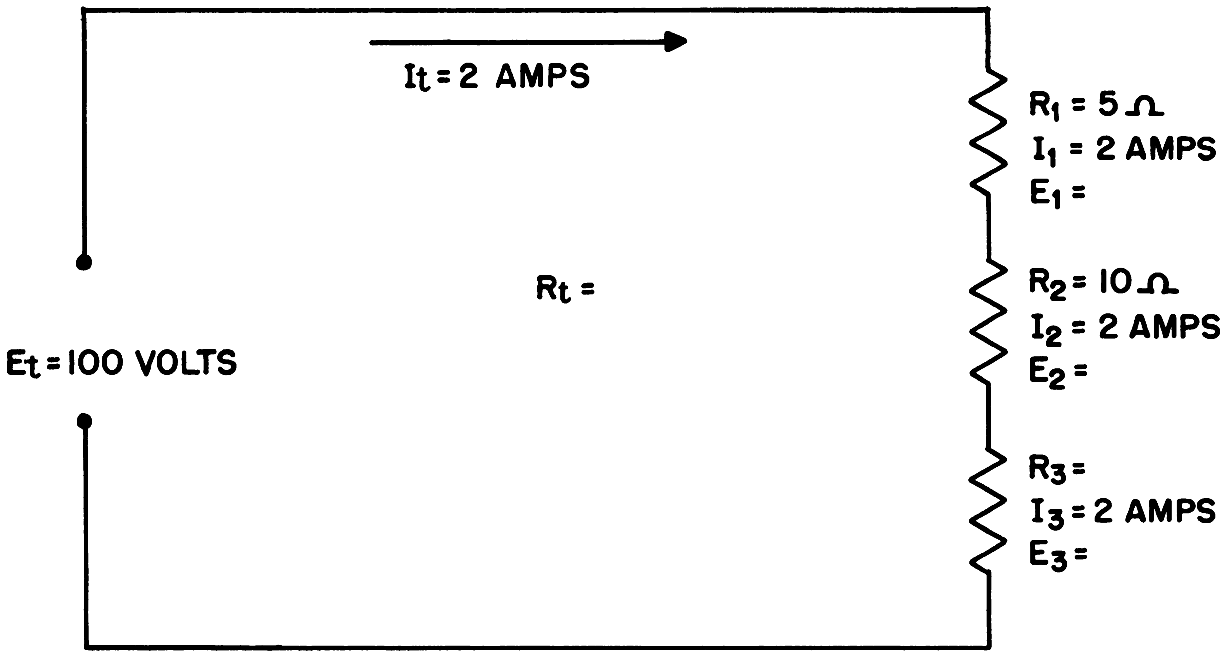
This is true even though the various resistors in the series circuit may all be of different values.

You can use Ohm's Law in working with series circuits, either as applied to the entire circuit or only to a part. It can only be used to find an unknown quantity for a certain part of the circuit when two factors are known.

PROBLEM: A circuit consisting of three resistors connected in series has an applied voltage of 100 volts and a current flow of 2 amperes. If two of the resistor values, R_1 and R_2, are known to be 5 ohms and 10 ohms respectively, but the third resistor value, R_3, is not known, the value of R_3 and the current and voltage for each resistor may be determined by applying Ohm's Law to each part of the circuit.

To find the unknown values, you should first make a simple sketch for recording the information which you already have and that which you will obtain as you use Ohm's Law for various parts of the circuit. This sketch will enable you to visualize the various components of the circuit and their relationships with one another.

Next you should record all of the known factors concerning each resistor.



You know that I_1, I_2, and I_3 are equal to I_t from the third characteristic of a series circuit.

To find R_t, you will use the equation for finding resistance.

$$R = \frac{E}{I} \text{ or } R_t = \frac{E_t}{I_t}$$

$$R_t = \frac{100}{2} = 50$$

To find E_1, you will use the equation for finding voltage.

$$E = IR \text{ or } E_1 = I_1 \times R_1$$

$$E_1 = 2 \times 5 = 10 \text{ volts}$$

To find E_2, you will use the same equation.

$$E = IR \text{ or } E_2 = I_2 \times R_2$$

$$E_2 = 2 \times 10 = 20 \text{ volts}$$

To find R_3 and E_3, you have a choice of two methods.

First Method: Find R_3 by using first characteristic of a series circuit.

$R_t = R_1$ plus R_2 plus R_3

$50 = 5$ plus 10 plus R_3

$R_3 =$ 50 minus 5 minus 10 = 35

then find E_3, by using Ohm's law equation for finding voltage.

$E = IR$ or $E_3 = I_3 \times R_3$

$E_3 = 2 \times 35 = 70$ volts

Second Method: Find E_3 by using second characteristic of a series circuit.

$E_t = E_1$ plus E_2 plus E_3

$100 = 10$ plus 20 plus E_3

$E_3 =$ 100 minus 10 minus 20 = 70 volts

then find R_3 by using Ohm's Law equation for finding resistance

$$R = \frac{E}{I} \text{ or } R_3 = \frac{E_3}{I_3}$$

$$R_3 = \frac{70}{2} = 35$$

The use of either method will give the same results.

JOB SHEET NO. 14

Fill in the blanks and solve for the unknown in the following problems.

1. Ohm's Law governs the____

____

2. Amperes equals____
3. Volts equals____
4. Ohms equals____
5. The three equations that express Ohm's Law mathematically are:
   a. I = ____________________
   b. E = ____________________
   c. R = ____________________

6. When solving for the value of part of a series circuit, use ______________________________

____

7. When solving for the value of the total circuit, use ______________________________

______________________________ .

8. 10 volts are applied across four known resistors connected in series, and the value of the resistors are: $R_1 = 20$ ohms, $R_2 = 30$ ohms, $R_3 = 50$ ohms, and $R_4 = 100$ ohms. What is the voltage across each resistor, the current through each resistor, and the total current flow and resistance?

Sketch Problem

R_t = ____________ ohms

I_t = ____________ amperes

I_t = ____________ milliamperes

I_1 = ____________ milliamperes

E_1 = ____________ volts

I_2 = ____________ milliamperes

E_2 = ____________ volts

I_3 = ____________ milliamperes

E_3 = ____________ volts

I_4 = ____________ milliamperes

E_4 = ____________ volts

9. The following sketch shows a series circuit that exists in the Power Drive Mk 4. Use the information given to calculate the unknown values.

Given:

Total current = 7.5 milliamperes
R_{32} = 3,000 ohms
R_{31} = 1800 ohms

Find:

Total applied voltage - E_t = ____________

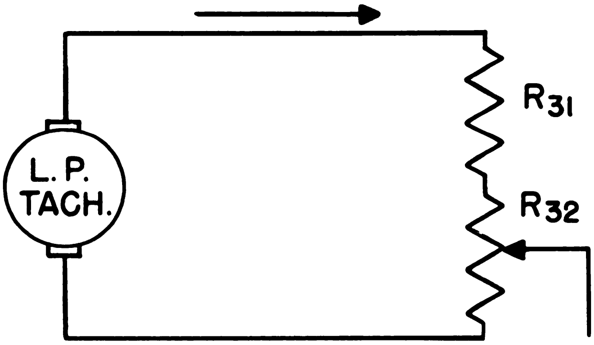
Total resistance - R_t = ____________

Current through R_{32} = ____________

Voltage across R_{32} = ____________

Current through R_{31} = ____________

Voltage across R_{31} = ____________



10. In the circuit shown in problem 9 the voltage across R_{31} is measured and found to be 10.8 volts. The values of R_{31} and R_{32} remain the same. Solve for the unknown values.

Total applied voltage = ______________ V

Total current flow = ______________ ma

Total resistance = ______________

Resistance of R_{31} = 1800

Current through R_{31} = ______________ ma

Voltage across R_{31} = 10.8 V

Resistance of R_{32} = 3,000 ma

Current through R_{32} = ______________ ma

Voltage across R_{32} = ______________ V

SECTION III

TOPIC 5

ELECTRICAL POWER

A. You have learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
3. The contents of d-c circuits.	
4. The basic characteristics of d-c series circuits.	
5. About Ohm's Law and its uses in a d-c series circuit.	
B. You are learning:	
1. What force, work, and electrical power are.	NavPers 10622-B, pages 61 to 64
2. What the units of electrical power are.	NavPers 10622-B, page 69
3. How electrical power is computed.	NavPers 10170, Vol. I, pages 24 and 25
4. What the power rating of equipment means and how it affects the size of equipment.	NavPers 10170, pages 24 and 25
C. You will acquire skill in:	
1. Computing electrical power in a series circuit.	
2. How to select equipment with the proper power rating.	

FORCE, WORK, AND ELECTRICAL POWER

Scientists and technicians make a point of specifically defining all the terms they use. They like their language to say exactly what they mean. This is necessary because scientists use technical terms in explaining their work. With a good working knowledge of such terms as force, work, power, emf, current, and resistance, you'll be far more "savvy" about your own work. Knowing exactly what certain words mean helps a lot.

You often hear the word force. But you use force far more often than you hear the word. Every time you lift something, you use force. Every time you move, you have exerted force. Force may be a push or a pull. Force then, is that which produces motion or tends to produce motion. The force which causes electrons to flow is an electromotive force and its unit is the volt. There are many kinds of force, but they all produce or tend to produce motion.

You can have force and still do no work. Imagine that you push with all your strength against a steel bulkhead. You probably think you've done work, but technically you haven't. True, you have exerted yourself on the bulkhead, but since the bulkhead hasn't moved, no work has been done. Force is exerted whenever a body is pushed or pulled but work is done if the body moves. WORK IS A FORCE ACTING THROUGH SPACE.

Work = force x distance

You have learned that the amount of work done has nothing to do with the time it takes to do the work. However, the amount of power depends on how fast that work can be done. You know that a steam shovel has a great deal more power than a man has. Both can do the same amount of work but the steam shovel will do it a lot faster. POWER IS THE RATE OF DOING WORK.

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

Whenever voltage causes electron movement, work is done in moving electrons from one point to another. The rate at which this work is done is called electrical power.

UNITS OF ELECTRICAL POWER

The basic unit of electrical power is the watt. One watt (w) is equal to one volt (v) multiplied by one ampere (a). For quantities of power of more than 1,000 watts, the unit used is the kilowatt (kw), while for quantities of power smaller than a watt, the unit used is the milliwatt (mw).

$$1 \text{ kw} = 1000 \text{ w}$$

$$1 \text{ mw} = \frac{1}{1000} \text{ w}$$

POWER FORMULAS AND COMPUTATION OF ELECTRICAL POWER

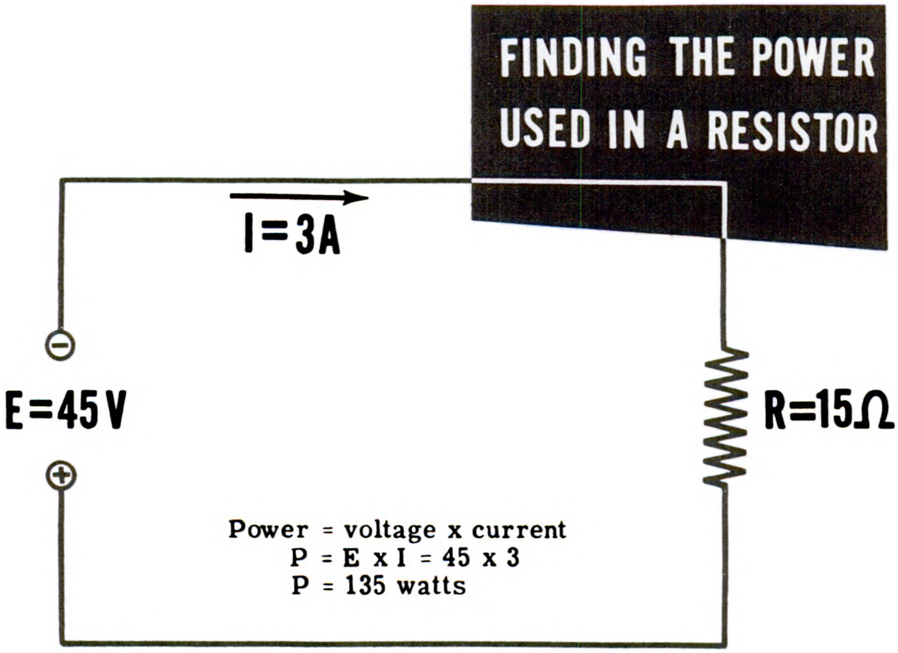
You have seen that the unit of electrical power is the watt, and that one watt equals one volt multiplied by one ampere. From this is derived the basic power formula:

$$\text{Power} = \text{current} \times \text{voltage}$$

or

$$P = IE$$

By use of this formula, you can determine the power in any circuit, or part of a circuit when the current and voltage are known.



Power = voltage x current
$P = E \times I = 45 \times 3$
$P = 135$ watts

CIRCUIT POWER USED IS 135 WATTS

By substituting Ohm's Law expressions in the formula for watts, the formula may be expressed in terms of current and resistance or voltage and resistance. According to Ohm's Law, $E = IR$. By replacing E in the power formula with its equal value (IR), power can be determined without knowing the voltage.

Power formula: $P = EI$

Substituting (IR) for E: $P = (IR)I$ or $I \times R \times I$

Since $I \times I$ is I^2: $P = I^2R$

NOTE: A quantity multiplied by itself is called a quantity "squared," and is written I^2 or R^2, etc.

Similarly, $I = \frac{E}{R}$ and, if $\frac{E}{R}$ is substituted for I in the power formula, power can be found with only the voltage and current known.

Power formula: $P = EI$

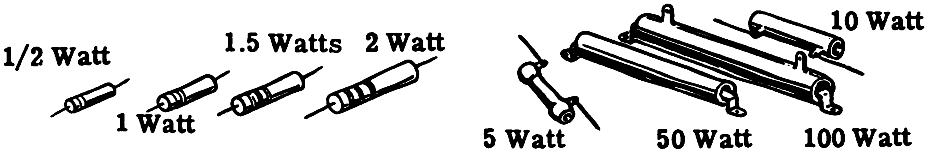
Substituting $\frac{E}{R}$ for I: $P = \frac{(E)}{R}$ or $\frac{E \times E}{R}$

Since ExE is E^2. $P = \frac{E^2}{R}$

POWER RATINGS

From your own experience you have probably found that most electrical equipment is rated for both voltage and power--volts and watts. Electrical lamps rated at 115 volts for use on a 115-volt line are also rated in watts, and are usually identified by wattage rather than volts. The wattage rating of an electrical lamp or other electrical energy is changed into another form of energy, such as heat, light, or mechanical motion. The faster a lamp changes electrical energy into light, the brighter the lamp will be; thus, a 100-watt lamp furnishes more light than a 75-watt lamp. Similarly, the wattage rating of motors, resistors, and other electrical devices indicates the rate at which they are designed to change electrical energy into some other form of energy. If the normal wattage rating is exceeded, the equipment or device will overheat and perhaps be damaged.

When more power is used in a resistance, the rate at which electrical energy is changed to heat increases and the temperature of the resistance rises. If the temperature rises too high, the material of the resistance may change its composition, expand, contract, or burn due to heat.



Resistors are rated in watts in addition to ohms of resistance. Resistors of the same resistance value are available in different wattage ratings of 1/3, 1/2, and 2 watts. The larger the size of carbon resistor the higher its wattage rating, since a larger amount of material will absorb and give up heat more easily.

When resistors of wattage ratings greater than 2 watts are needed, wire-wound resistors are used. Such resistors are made up of ranges between 5 and 200 watts, with special types being used for power in excess of 200 watts.

ELECTRICAL POWER

JOB SHEET NO. 15

1. Force is ______________________________
2. Work is ______________________________
3. Work is done only ______________________________
4. Power is ______________________________
5. The watt is ______________________________
6. Power in a circuit equals ______________________________
7. Milliwatts are used when power is ______________________________
8. Kilowatts are used when power is ______________________________
9. Exceeding the power rating of electrical devices ______________________________
10. The following sketch shows a circuit found in Power Drive Mk 4. Solve for the power given by R^{31}, R^{32}, and RT.

Given:

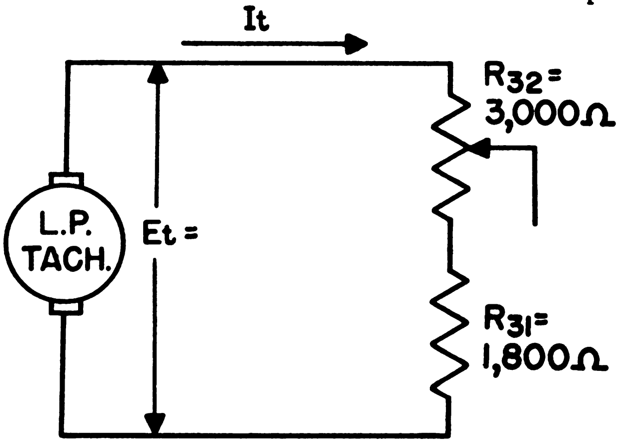
$R^{31} = 1800$ ohms
$R^{32} = 3000$ ohms
Voltage across $R^{31} = 9$ volts d-c

Find:

Power across R^{31} ____________

Power consumed by R^{32} ______

Power consumed by RT ______



11. The following sketch shows another circuit found in Power Drive Mk 4. Solve for the unknown values listed below.

Given:

$R^{11} = 15{,}000$ ohms
$R^{10} = 5{,}000$ ohms
$R^{14} = 2{,}000$ ohms
$R^{13} = 350$ ohms
Voltage across $R^{11} = 30$ volts d-c

Find:

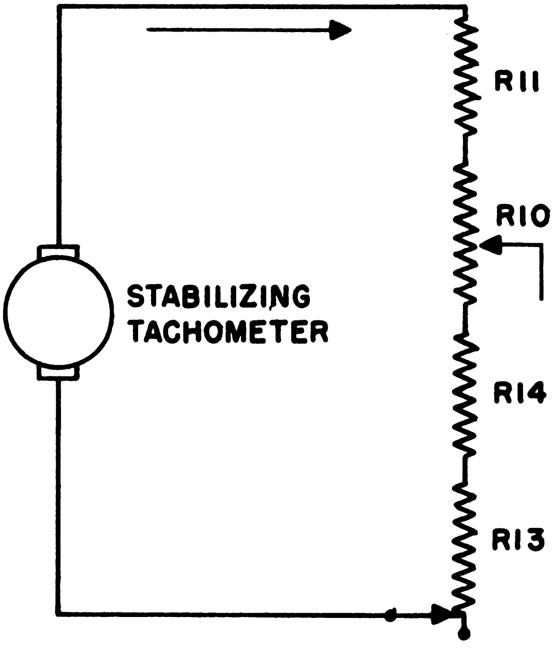
Power consumed by R^{11} ____________

Power consumed by R^{10} ____________

Power consumed by R^{14} ____________

Power consumed by R^{13} ____________

Power output of stabilizing tachometer ____________



12. Determine the power ratio of the following equipment, in Power Drive Mk 4, from the name plate data:

    a. Fan motor____

    b. D-c drive motor____________________________________

    c. Stabilizing tachometer________________________________

SECTION III

TOPIC 6

D-C PARALLEL CIRCUITS

A. You have learned: References:

1. About Fire Control in general.
2. About electricity fundamentals.
3. The contents of d-c circuits.
4. The basic characteristics of d-c series circuits.
5. About Ohm's Law and its uses in d-c series circuits.
6. About power in d-c series circuits.

B. You are learning:

1. How parallel circuits are connected.	NavPers 10622-B, pages 85 and 86
2. About resistance in a parallel circuit.	NavPers 10622-B, pages 89 to 91
3. About current in a parallel circuit.	NavPers 10622-B, pages 87 and 88
4. About voltage in a parallel circuit.	NavPers 10622-B, pages 86 and 87
	NavPers 10170, pages 6 to 10

C. You will acquire skill in:

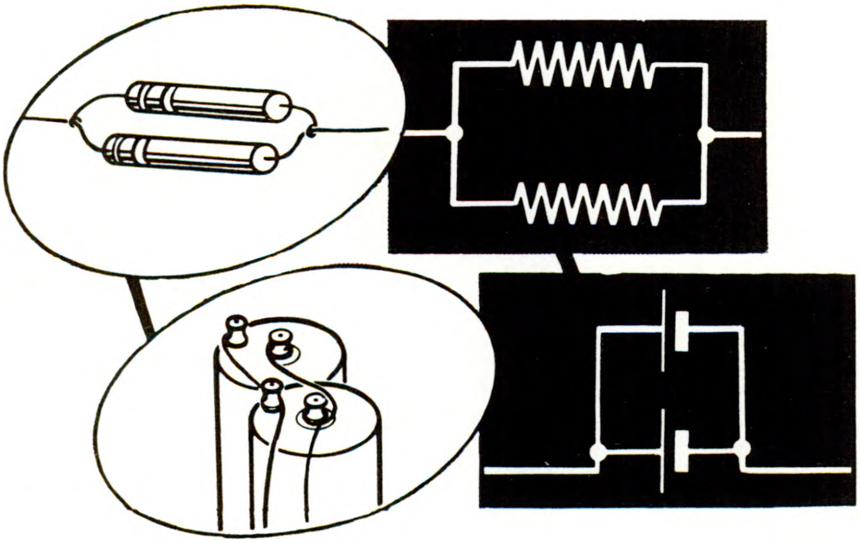
1. Solving basic d-c parallel problems

PARALLEL CIRCUIT CONNECTIONS

Electrical devices connected side by side are parallel connected. Polarized equipment connected positive to positive and negative to negative are also parallel connected.

Devices connected in parallel have more than one path for current flow, and the devices have to have approximately the same voltage rating, because they have the same applied voltage.

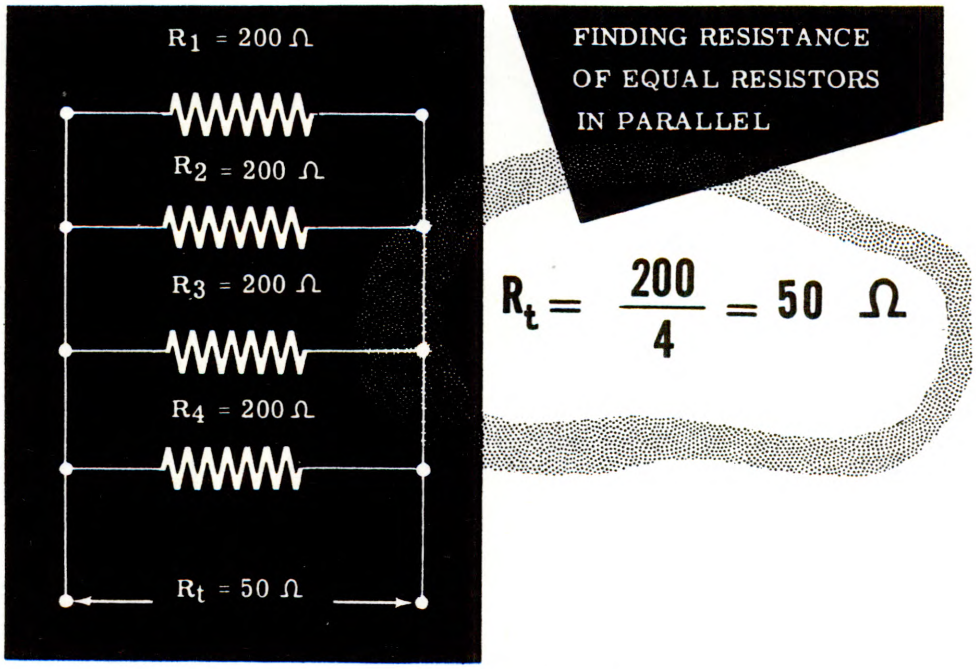
If two resistors, or sources, are connected as shown below, they are parallel connected.



PARALLEL CONNECTIONS

RESISTORS IN PARALLEL

Parallel-connected resistances increase the cross section of the total circuit, hence cause the resistance of the total circuit to be less than that of the smallest single resistance. As more resistors are added in parallel, the total resistance decreases and the total current increases. Also, if resistors are disconnected, the total resistance increases and less current will flow.



EQUAL RESISTORS IN PARALLEL

The total resistance of equal resistors connected in parallel equals the value of one resistance divided by the number of resistors. Suppose that your circuit consists of four 200-ohm resistances in parallel. The total resistance of the parallel connection is one-fourth that of a single 200-ohm resistance, or equal to 50 ohms. This parallel connection will act in the circuit as though it were a single 50-ohm resistance.

The total resistance of two unequal resistors is found in the following three steps:

1. Multiply the two resistance values.
2. Add the two resistance values.
3. Divide the product by the sum.

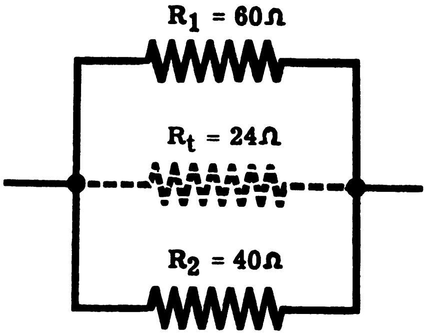
This formula is expressed as follows:

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$$

The formula shows that R_t equals the product of R_1 and R_2 divided by their sum. To find R_t the numerical values of R_1 and R_2 are used and the three steps to the solution are performed.

$$R_t = \frac{60 \times 40}{60 + 40}$$

1. Multiply — $R_t = \frac{60 \times 40}{60 + 40} = \frac{2400}{60 + 40}$
2. Add — $R_t = \frac{2400}{60 + 40} = \frac{2400}{100}$
3. Divide — $R_t = \frac{2400}{100} = 24$ ohms



Combinations of three or more unequal resistances in parallel are sometimes used. To find the resistance of such combinations, you first find the total resistance of any two of the resistances. Combine this total in the same way with another of the resistance values and you have the total for three resistances. Continue to combine the total with additional resistances until all of the resistances have been combined to give the total resistance of all the parallel resistances.

For example, if three resistors--R_1, R_2 and R_3--are connected in parallel, you would first find the total resistance of R_1 and R_2 in parallel. Next you combine this value with R_3 and obtain the total resistance of R_1, R_2 and R_3. This total is the total resistance of the three resistors in parallel.

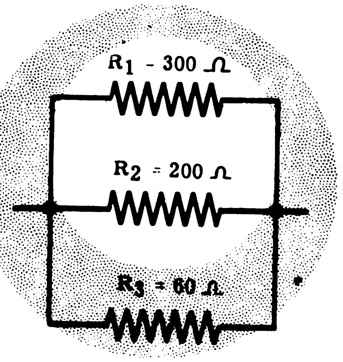
If R_1 equals 300 ohms, R_2 equals 200 ohms and R_3 equals 60 ohms, the total resistance is found by combining 300 ohms and 200 ohms and then combining this result with 60 ohms.

Combining R_1 and R_2

$$R_a = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_a = \frac{300 \times 200}{300 + 200} = \frac{60{,}000}{500} = 120$$

$$R_a = 120\ \Omega$$

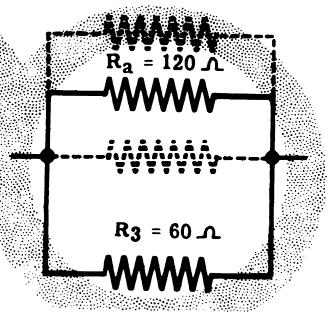


Combining R_a and R_3

$$R_t = \frac{R_a \times R_3}{R_a + R_3}$$

$$R_t = \frac{120 \times 60}{120 + 60} = \frac{7200}{180} = 40$$

$$R_t = 40\ \Omega$$



There may be times when R_t and all but one resistance in parallel are known. The unknown resistance is found by the formulas:

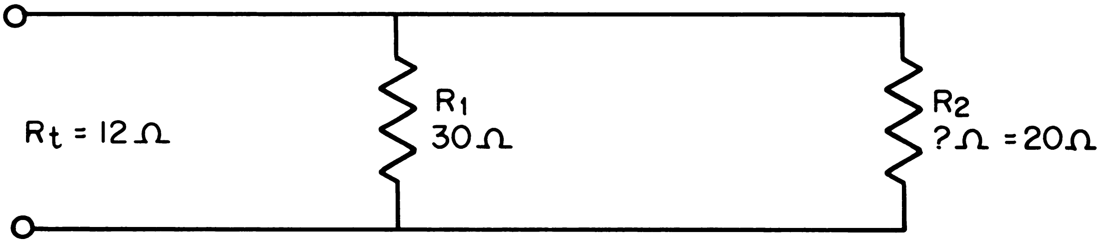
$$R_2 = \frac{R_t \times R_1}{R_1 - R_t} \text{ or } R_1 = \frac{R_t \times R_2}{R_2 - R_t}.$$

If R_1 equals 30 ohms and R_t equals 12 ohms, R_2 can be found in the following manner:

$$R_2 = \frac{R_t \times R_1}{R_1 - R_t}$$

$$R_2 = \frac{12 \times 30}{30-12} = \frac{360}{18} = 20$$

$$R_2 = 20 \text{ ohms}$$

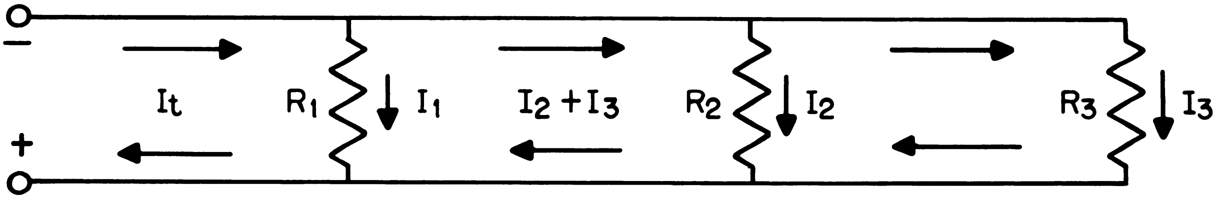


CURRENT IN PARALLEL

For parallel circuits consisting of equal resistances in parallel, the circuits through each resistor will be equal, since each path offers an equal amount of opposition to current flow. In such a circuit the current through each resistance is equal to the total current divided by the number of resistances in parallel.

When unequal resistances are connected in parallel, the opposition to current flow is not the same for each branch of the circuit. A small value of resistance offers less opposition, and thus, the smaller resistances in parallel circuits pass more current than the larger resistances.

In the following parallel circuit, if the resistors are equal, the current flow through the resistors will be equal. If R_1 is twice as large as R_2 and R_3, the current flow through R_1 will be half the value of R_2 and R_3.

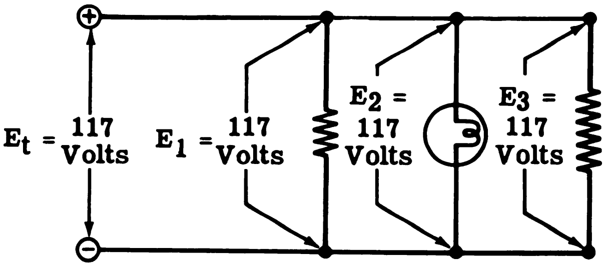


The total current is equal to the sum of all the currents through the separate branches. The formula for total current is:

$$I_t = I_1 \text{ plus } I_2 \text{ plus } I_3$$

VOLTAGE IN PARALLEL

Parallel resistances connected across a voltage source have the same voltage applied to each resistance, although the currents may differ depending on the value of resistance. All resistances which are to be connected in parallel must have the same voltage rating for proper operation, though each may pass a different amount of current.



PARALLEL CIRCUIT VOLTAGES

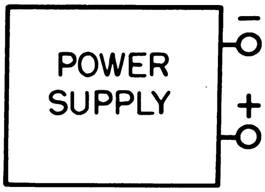
The total voltage is equal to the voltage across any one of the separate resistances. The formula for total voltage is:

$$E_t = E_1 = E_2 = E_3$$

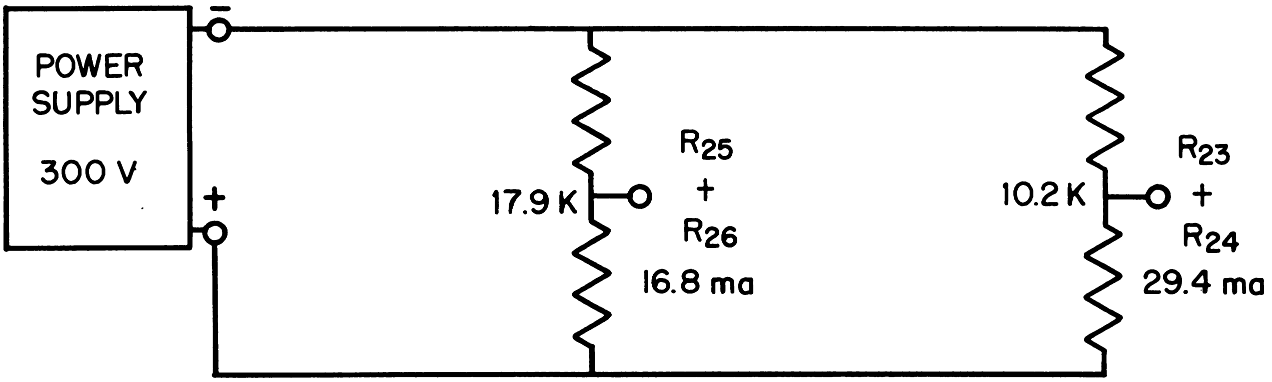
JOB SHEET NO. 16

Fill in the answers and solve the following problems.

1. Complete the following drawing by adding R_1, R_2, R_3, and R_4 in parallel to the power supply.



2. The following sketch was taken from OP 821A, figure 104. Solve for the unknown values.



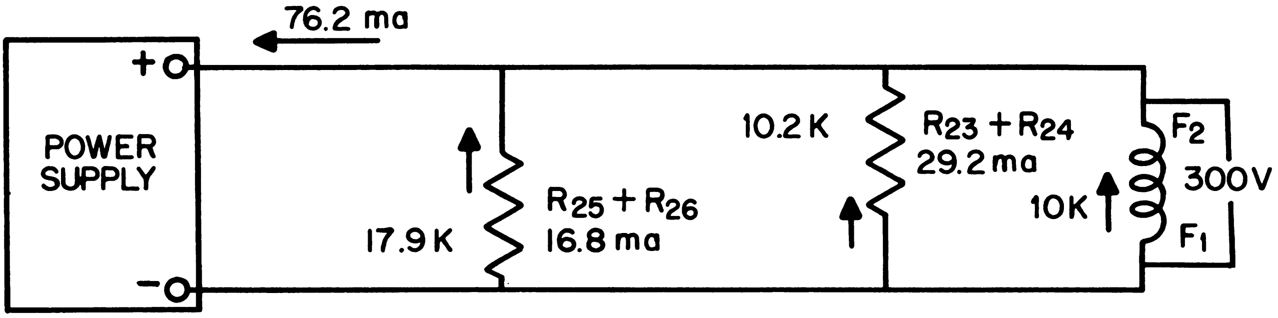
a. R_t = ____________________

b. E_{25} plus E_{26} = ____________

c. E_{23} plus E_{24} = ____________

d. I_t = ____________________

3. The following sketch was taken from OP 821A, figure 104, and simplified.



Find:

a. R_t = ____________________

b. E_{23} plus E_{24} = ____________

c. E_{25} plus E_{26} = ____________

d. E_t = ____________________

e. IF_1F_2 = ____________________

4. Draw a sketch of a parallel circuit, showing R_1, R_2, and R_t.

Give the formulas for finding the following without using Ohm's Law.

a. R_t =

b. R_1 =

c. R_2 =

d. E_t =

e. I_t =

f. I_1 =

g. I_2 =

SECTION III

TOPIC 7

OHM'S LAW--PARALLEL CIRCUITS

A. You have learned:

1. About Fire Control in general.
2. About electricity fundamentals.
3. The contents of d-c circuits.
4. The basic characteristics of d-c series circuits.
5. About Ohm's Law and its uses in d-c series circuits.
6. About power in d-c series circuits.
7. The basic characteristics of d-c parallel circuits.

B. You are learning:	References
1. How to use Ohm's Law to find resistance in parallel circuits.	NavPers 10622-B, pages 89 to 91
2. How to use Ohm's Law to find current in parallel circuits.	NavPers 10622-B, pages 87 and 88
3. How to find power in parallel circuits.	NavPers 10622-B, pages 91 to 96

C. You will acquire skill in:

1. Using Ohm's Law to find current and resistance in parallel circuits.
2. Finding power used by all, or parts, of a parallel circuit.

FINDING RESISTANCES IN PARALLEL CIRCUITS

Remember, when you applied Ohm's Law to a series circuit, you had to keep in mind the characteristics of a series circuit? The same is true when applying Ohm's Law to parallel circuits. The characteristics of parallel circuits to remember are:

1. The VOLTAGE is the same across all branches of a parallel circuit.

$$E_t = E_1 = E_2 = E_3, \text{ etc.}$$

2. The TOTAL CURRENT IN A PARALLEL CIRCUIT is the SUM of all the currents of all the branches.

$$I_t = I_1 \ I_2 \ I_3$$

3. The more loads added in parallel, the less the TOTAL resistance.

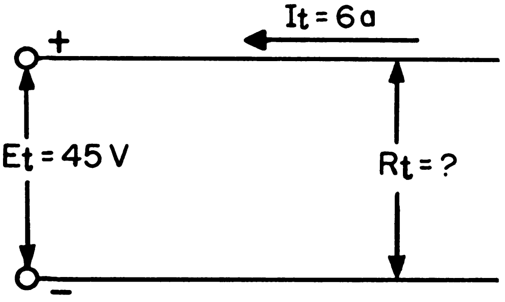
$$R_t = \frac{R_1 \times R_2}{R_1 \quad R_2}$$

Remember, also, to use the total values of the circuit when solving for the total value, and the values of the part of the circuit when solving for that part.

Now that you remember all this, let's solve a problem.

PROBLEM: Three resistors--R_1, R_2, and R_3--of unknown value, are connected in parallel across 45 volts. The total circuit current is 6 amperes and the current flowing through R_1 is 1.5 amperes. The current flowing through R_2 is 3 amperes, and the current flowing through R_3 is unknown.

1. Complete the circuit and the known values.



2. Find R_1 by using Ohm's Law.

$$E_1 = E_t$$

$$R = \frac{E}{I},\ R_1 = \frac{E_1}{I_1} = \frac{45}{1.5} = 30 \text{ ohms}$$

3. Find R_2 by using Ohm's Law.

$$E_2 = E_t$$

$$R = \frac{E}{I},\ R_2 = \frac{E_2}{I_2} = \frac{45}{3} = 15 \text{ ohms}$$

4. Find the current through R_3 by using the rule of current in parallel circuits.

$$I_t = I_1 + I_2 + I_3$$

$$6 = 1.5 + 3 + I_3$$

$$I_3 = 6 + 1.5 + 3 = 1.5 \text{ a}$$

5. Find R_3 by using Ohm's Law.

$$R = \frac{E}{I},\ R_3 = \frac{E_3}{I_1} = \frac{45}{1.5} = 30 \text{ ohms}$$

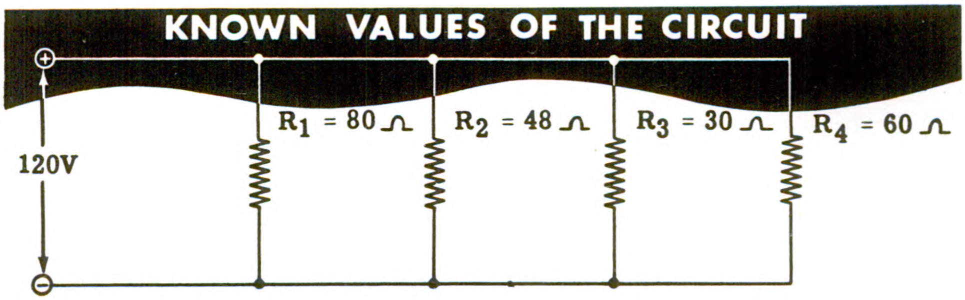
6. Find R_t by using Ohm's Law.

$$R = \frac{E}{I},\ R_t = \frac{E_t}{I_t} = \frac{45}{6} = 7.5 \text{ ohms}$$

NOTE: R_t could have been found by using the formula for total resistance in a parallel circuit. However, the computations would have been more complicated.

FINDING CURRENTS IN PARALLEL CIRCUITS

To solve for currents in parallel circuits you use the same procedure as that used in solving for resistances, except that the unknown quantities are currents. For example, a parallel circuit consists of four resistors--R_1, R_2, R_3, and R_4--connected across 120 volts. If the resistance of R_1 is 80 ohms, R_2 is 48 ohms, R_3 is 30 ohms, and R_4 is 60 ohms, the individual resistor currents can be obtained by applying Ohm's Law; and the total circuit current will equal the sum of these currents. Knowing the circuit voltage and total current, you can find the total circuit resistance.



KNOWN VALUES OF THE CIRCUIT

1. Find the resistor currents by using Ohm's Law. $I = \frac{E}{R}$

$$I_1 = \frac{E_1}{R_1} = \frac{120}{80} = 1.5\text{a} \qquad I_3 = \frac{E_3}{R_3} = \frac{120}{30} = 4\text{a}$$

$$I_2 = \frac{E_2}{R_2} = \frac{120}{48} = 2.5\text{ a} \qquad I_4 = \frac{E_4}{R_4} = \frac{120}{60} = 2\text{ a}$$

2. The total circuit current equals the sum of the branch currents.

$$I_t = I_1 + I_2 + I_3 + I_4$$

$$I_t = 1.5 + 2.5 + 4 + 2$$

$$I_t = 10\text{ a}$$

3. Find the total resistance by using Ohm's Law. $R = \frac{E}{I}$

$$R_t = \frac{E_t}{R_t} = \frac{120}{10} = 12 \text{ ohms}$$

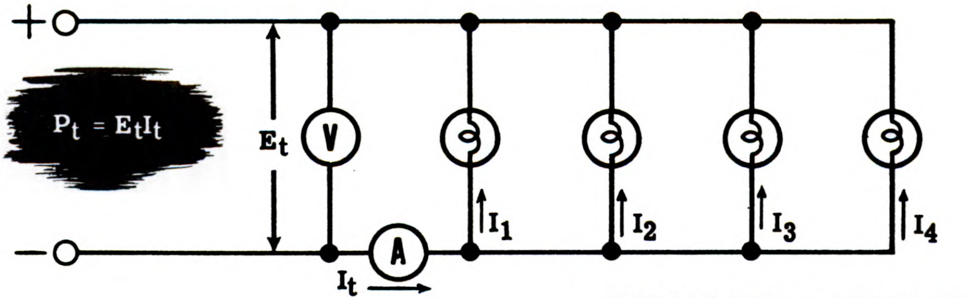
You can check the total resistance by using the parallel resistance formula.

Parallel circuit voltage may also be found by using Ohm's Law. Since the voltage across each resistor is equal in a parallel circuit, the circuit voltage can be found if the values of resistance and current are both known for any of the circuit resistors.

POWER IN PARALLEL CIRCUITS

You have seen that the power used by a resistor is equal to the current through the resistor multiplied by the voltage across the resistor ($P = EI$), and you have also seen how the total power in a series circuit is equal to the sum of the powers used by each resistance in the circuit. This also is true in parallel circuits; that is, the total power used by a parallel circuit is equal to the sum of the power used by all resistances in the circuit, and can be found by multiplying the total voltage across the circuit by the total circuit current.

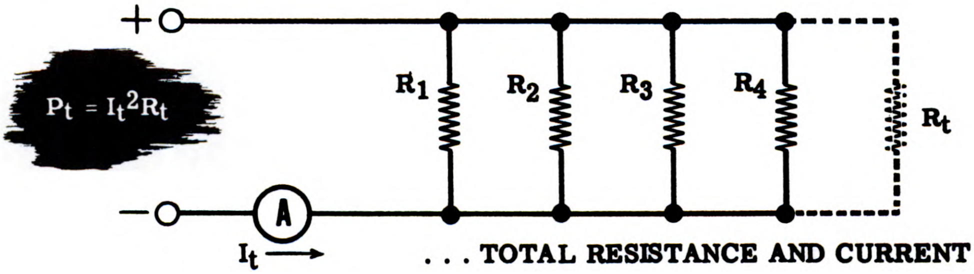
TOTAL POWER IN A PARALLEL CIRCUIT . . .



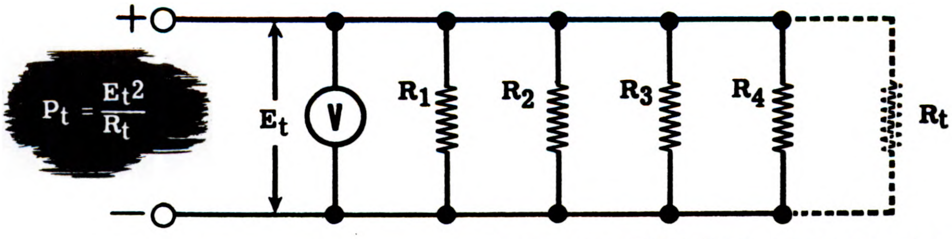
. . . EQUALS TOTAL VOLTAGE TIMES TOTAL CURRENT

The circuit power can also be found by using the rules for parallel circuits to find the total resistance of the circuit in the resistance of all the parts is known. Then total power can be determined by measuring either circuit current or voltage and using the alternate power formulas.

FINDING TOTAL POWER USING . . .



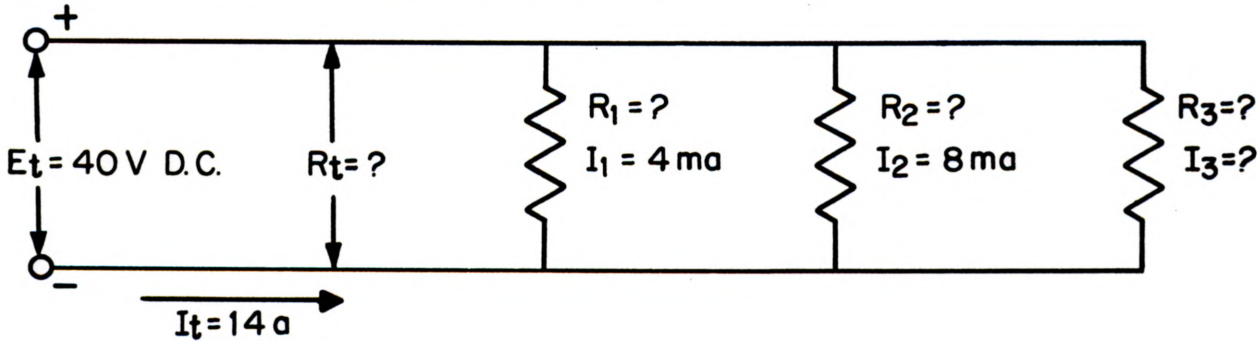
. . . TOTAL RESISTANCE AND CURRENT



. . . TOTAL RESISTANCE AND VOLTAGE

JOB SHEET NO. 17

1. Solve for the unknown values in the following problem.



R_1 = ____________________

R_2 = ____________________

R_3 = ____________________

R_t = ____________________

I_3 = ____________________

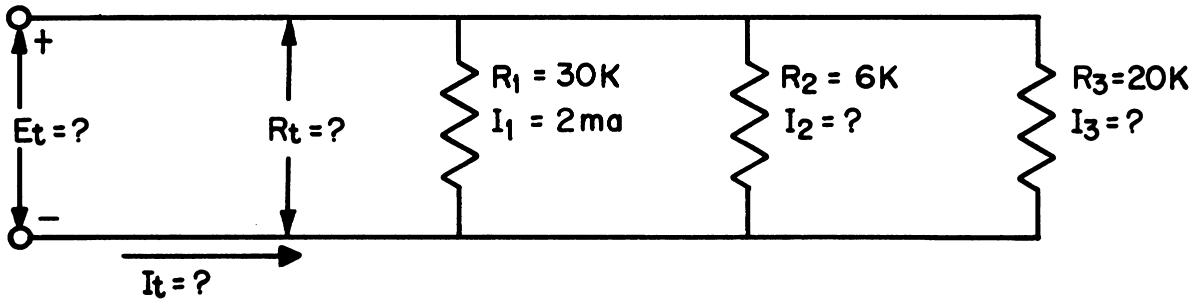
P_1 = ____________________

P_2 = ____________________

P_3 = ____________________

P_t = ____________________

2. Solve for the unknown values in the following problem.



E_t = ____________________

E_1 = ____________________

E_2 = ____________________

E_3 = ____________________

I_2 = ____________________

I_3 = ____________________

I_t = ____________________

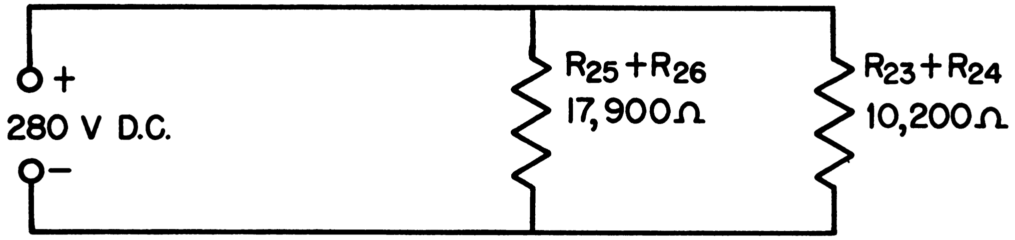
P_1 = ____________________

P_2 = ____________________

P_t = ____________________

P_3 = ____________________

3. The following diagram is a simplified circuit that exists in the amplifiers of Power Drive Mk 4. Solve for the unknown values.



R_t = ____________

I_t = ____________

P_t = ____________

$I_{25} + I_{26}$ = ____________

$I_{23} + I_{24}$ = ____________

$P_{25} + P_{26}$ = ____________

$P_{23} + P_{24}$ = ____________

TOPIC 8

D-C SERIES--PARALLEL CIRCUITS

A. You have learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
3. The contents of d-c circuits.	
4. The basic characteristics of d-c series circuits.	
5. About Ohm's Law and its uses in d-c series circuits.	
6. About power in d-c series circuits.	
7. The basic characteristics of d-c parallel circuits.	
8. About Ohm's Law and its uses in d-c parallel circuits.	
B. You are learning:	
1. About series-parallel connections.	NavPers 10622-B, page 97 and 98
2. About resistance in series-parallel circuits.	NavPers 10622-B, page 103
3. About current in series-parallel circuits.	NavPers 10622-B, page 102
4. About voltage in series-parallel circuits.	NavPers 10622-B, page 102
5. About bridge circuits.	

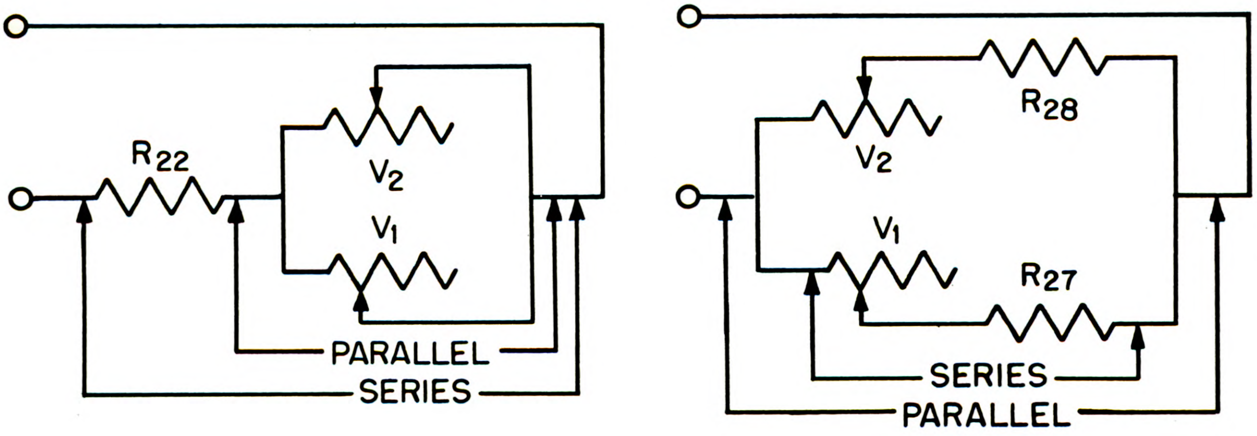
C. You will acquire skill in:

1. Solving series-parallel problems.

SERIES-PARALLEL CONNECTIONS

Series-parallel circuits contain both series and parallel-connected devices. Circuits consisting of three or more devices may be connected in a complex circuit, partially series and partially parallel. There are two basic types of series-parallel circuits: one, in which a device is connected in series with a parallel combination, and the other in which one or more branches of a parallel circuit consist of resistances in series.

Most of your circuits in the power drive are series-parallel connected and can be broken down into a number of simple series and parallel circuits. The following simplified sketches were taken from OP 821A, figure 104.



TWO TYPES OF SERIES PARALLEL CIRCUITS

RESISTANCE IN SERIES-PARALLEL CIRCUITS

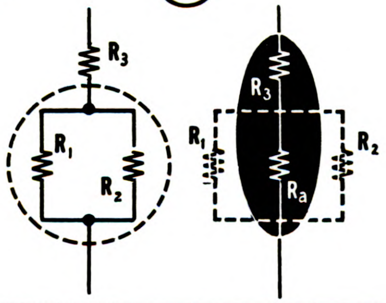
A series-parallel circuit can be simplified to a single equivalent resistance by using the formulas for series and parallel resistances.

Before using the rules for series and parallel resistances, you must decide what steps to use in simplifying the circuit. No new formulas are needed to find the total resistance of resistances connected in series-parallel. Instead, you break the complete circuit into parts consisting of simple series and parallel circuits, then solve each part separately and combine the parts.

A

Combine R_1 and R_2 to find total resistance (R_a) of parallel combination

$$R_a = \frac{R_1 \times R_2}{R_1 + R_2}$$



Add R_a and R_3 to find total circuit resistance (R_t)

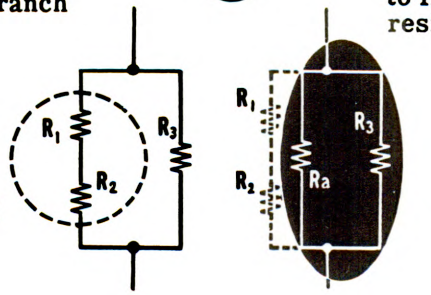
$$R_t = R_a + R_3$$

FINDING THE TOTAL RESISTANCE OF SERIES-PARALLEL CIRCUIT

B

Add R_1 and R_2 to find total resistance (R_a) of series-connected branch

$$R_a = R_1 + R_2$$

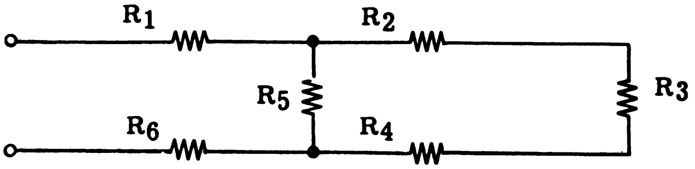


Combine the parallel combination of R_a and R_3 to find the total circuit resistance (R_t)

$$R_t = \frac{R_a \times R_3}{R_a + R_3}$$

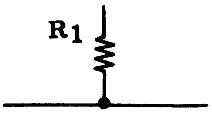
Complex circuits should be redrawn or straight-lined before combining resistances. The more complicated circuits require more steps, but no different methods.

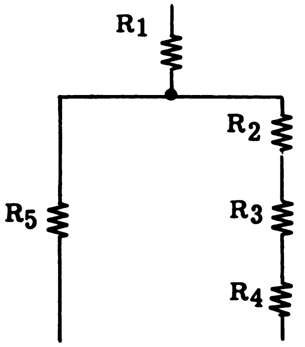
THE ORIGINAL CIRCUIT



1. Start at one end of the circuit and draw all series resistances in a straight line until you reach a point where the circuit has more than one path to follow. At that point draw a line across the end of the series resistance.

❶



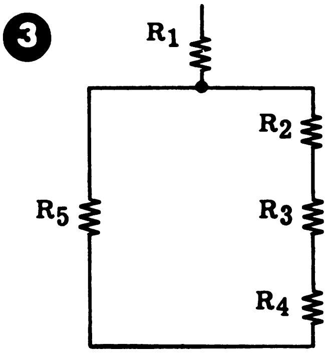


❷

2. Draw the parallel paths from this line in the same direction as the series resistances.

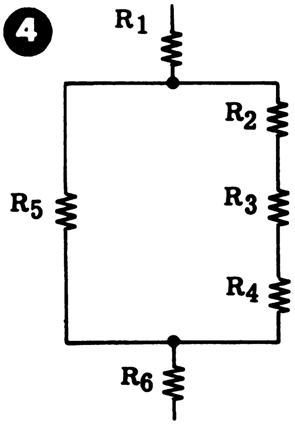
3. Where the parallel paths combine, a line is drawn across the ends to join the paths.

❸



4. The circuit is continued from the center of the parallel connecting line, adding the series resistance to complete the redrawn circuit.

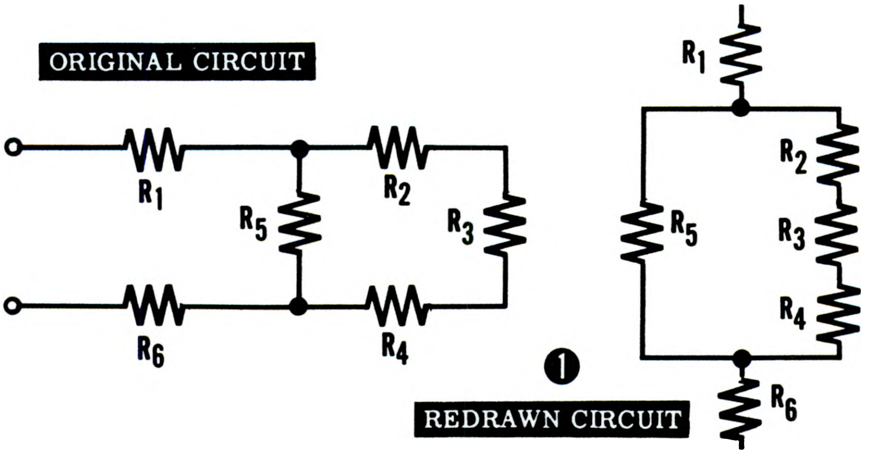
❹



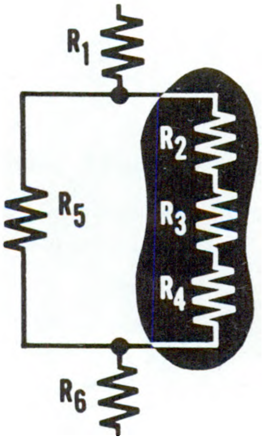
The basic steps in finding the total resistance of a complex series-parallel circuit are as follows--

1. Redraw the circuit if necessary.
2. If any of the parallel combinations have branches consisting of two or more resistors in series, find the total value of these resistors by adding them.

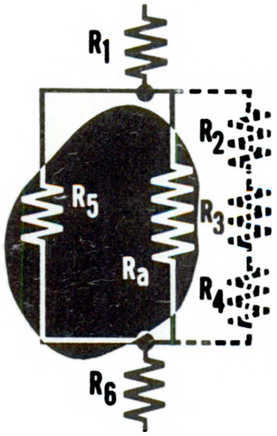
3. Using the formula for parallel resistances, find the total resistance of the parallel parts of the circuit.
4. Add the combined parallel resistances to any resistances which are in series with them.



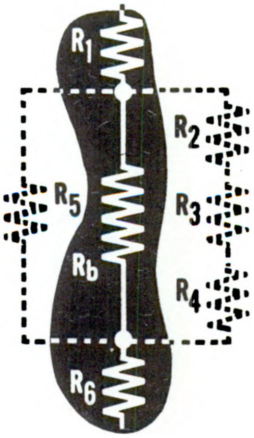
② Add the series branches



③ Combine parallel part of circuit



④ Add the series-connected resistance values



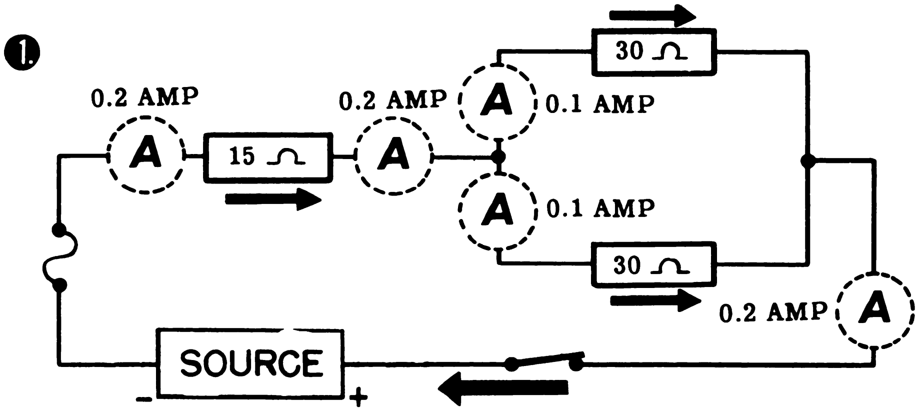
CURRENT IN SERIES-PARALLEL CIRCUITS

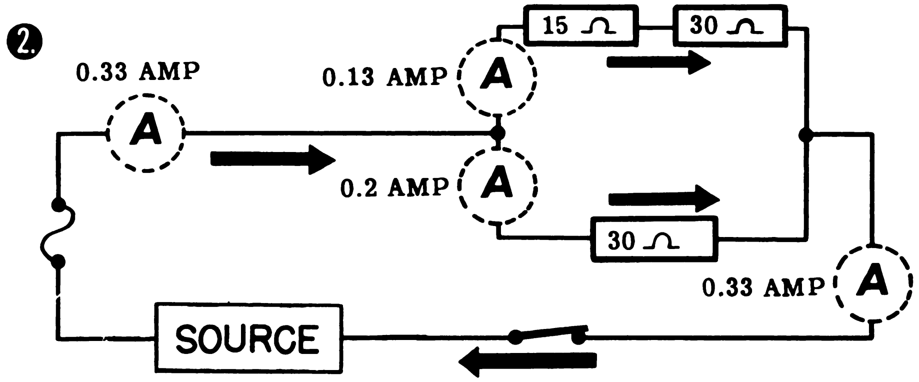
Current through each branch of a series-parallel circuit depends on the resistance of that branch and the applied voltage.

The total circuit current for a series-parallel circuit depends upon the total resistance offered by the circuit when connected across a voltage source. Current flow in the circuit will divide to flow through all parallel paths and come together again to flow through series parts of the circuit. It will divide to flow through a branch circuit and then repeat this division if the branch circuit subdivides into secondary branches.

As in parallel circuits, the current through any branch resistance is inversely proportional to the amounts of resistance--the greater current flows through the least resistance. However, all of the branch currents always add to equal the total circuit current.

The total circuit current is the same at each end of a series-parallel circuit and equals the current flow through the voltage source.



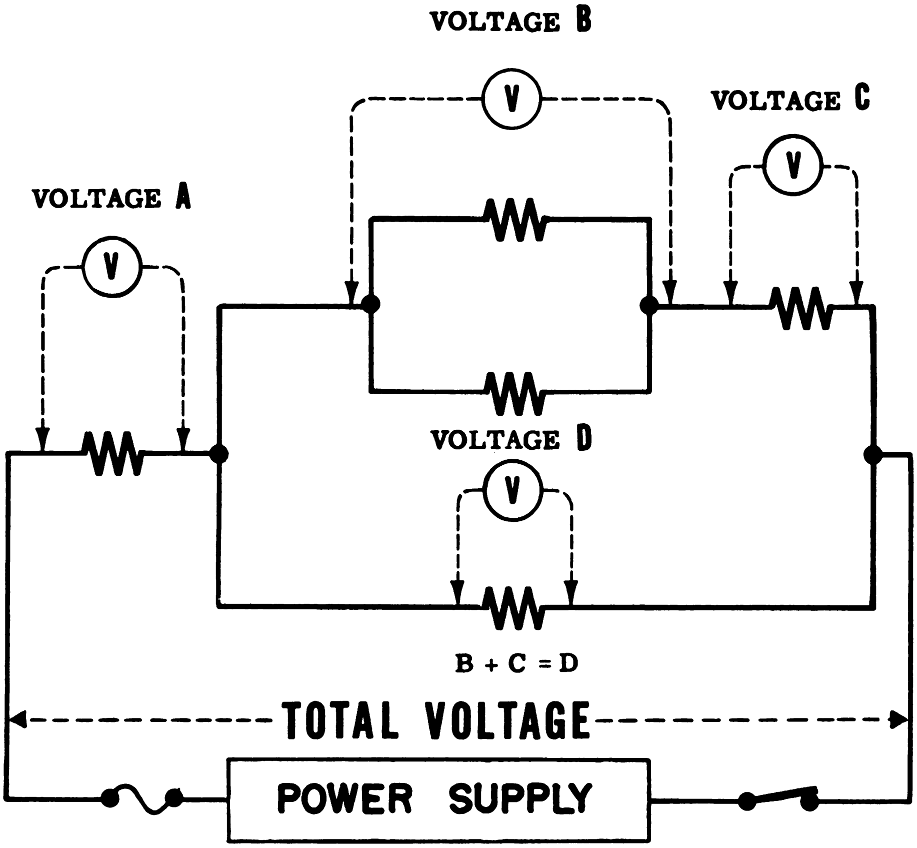


VOLTAGE IN SERIES PARALLEL CIRCUITS.

Voltage drops across a series-parallel circuit occur in the same way as in series and parallel circuits. Across series parts of the circuit the voltage drops are equal only for equal resistances, while across parallel parts of the circuit the voltage across each branch is the same.

Series resistances forming a branch of a parallel circuit will divide the voltage across the parallel circuit. In a parallel circuit consisting of a branch with a single resistance and a branch with two series resistances, the voltage across the single resistor equals the sum of the voltages across the two series resistances. The voltage across the entire parallel circuit is exactly the same as that across either of the branches.

The voltage drops across the various paths between the two ends of the series-parallel circuit always add up to the total voltage applied to the circuit.

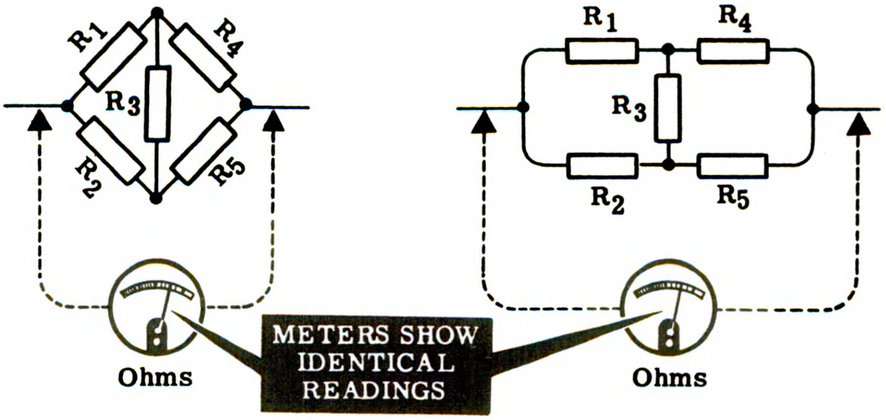


VOLTAGES A+D=TOTAL VOLTAGE
VOLTAGES A+B+C = TOTAL VOLTAGE

BRIDGE CIRCUITS

The type of series-parallel circuit connected in the following manner is called a bridge circuit. Because of the manner in which R_3 is connected in the circuit, the usual method of breaking down series-parallel circuits cannot be used to find the total resistance. Although you could find the total resistance by using very complex mathematical formulas, there are two easy and simple methods you can use--direct measurement and Ohm's Law.

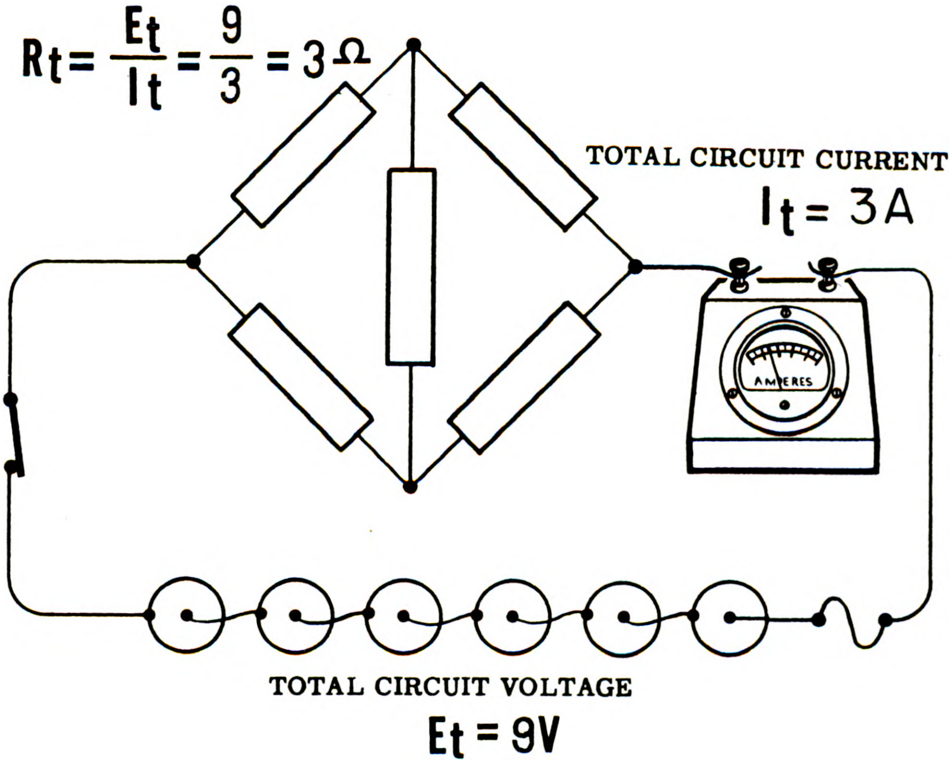
With resistors connected to form the circuits, measure the total resistance across the circuit with an ohmmeter.



Another way you can find the total resistance of a bridge-connected series-parallel circuit is to apply Ohm's Law to the circuit. To do this you apply a known voltage--such as is obtained from a battery or power supply--across the circuit and measure the total current. From the voltage and current values the circuit resistance is determined.

For example, connect the following circuit across a 9-volt dry cell battery and measure the circuit current flow with an ammeter inserted in one lead to the battery. Total current is three amperes. What is total resistance? It is three ohms as determined by Ohm's Law.

The resistance of any part of the circuit can be found by applying Ohm's Law to that part of the circuit.



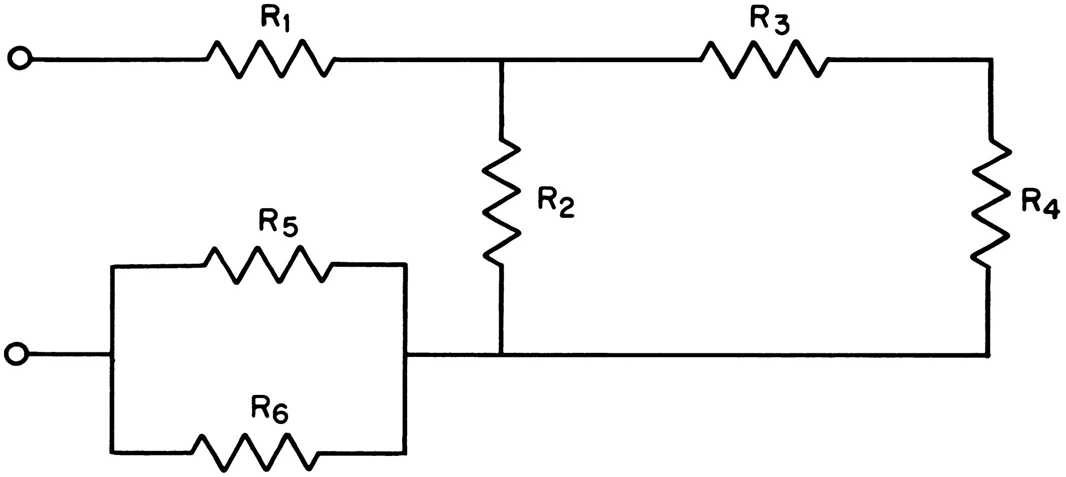
JOB SHEET NO. 18

Complete the following diagrams and solve the following problems.

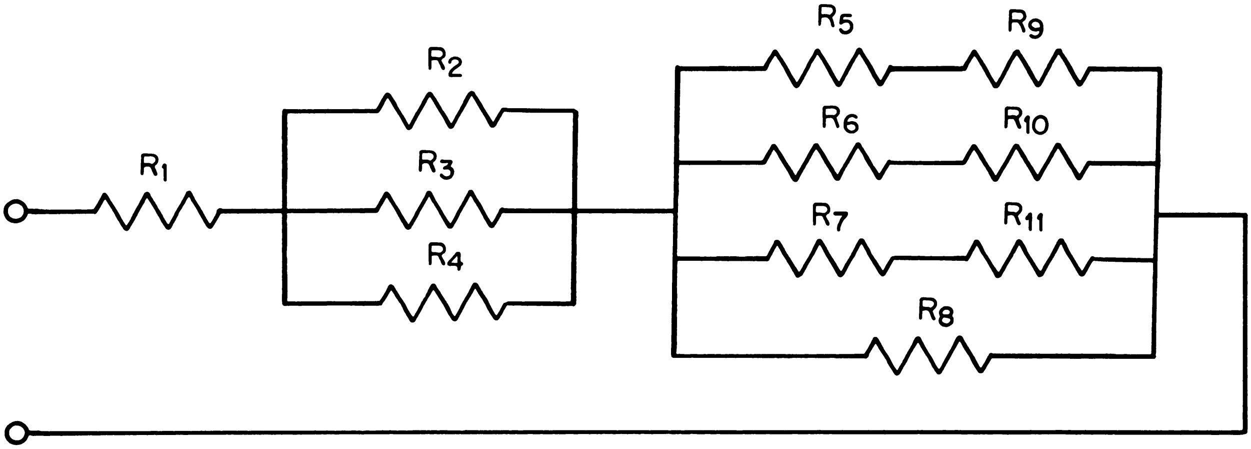
1. Sketch R_1 and R_2 in series with a group of parallel resistors, R_3, R_4, and R_5 across a power supply.

2. Sketch R_1, R_2, and R_3, in parallel with a group of series resistors, R_4 and R_5 across a d-c generator.

3. Straight-line the following circuit.



4. Solve for the unknown values.



R_1 = 225 ohms

E_1 =

I_1 =

R_2 = 75 ohms

E_2 =

I_2 =

R_3 =

E_3 = 75 ohms

I_3 =

R_4 =

E_4 = 5 v

I_4 =

R_5 = 1k

E_5 = 33 1/3 v

I_5 =

R_6 = 750 ohms

E_6 =

I_6 = 33 1/3 ma

R_7 = 250 ohms

E_7 =

I_7 = 100 ma

R_8 = 1.5 k

E_8 = 50 v

I_8 =

R_9 =

E_9 =

I_9 =

R_{10} =

E_{10} =

I_{10} =

R_{11} =

E_{11} =

I_{11} =

R_T =

E_T =

I_T =

SECTION III

TOPIC 9

KIRCHHOFF'S LAWS

A. You have learned:

1. About Fire Control in general.
2. About electricity fundamentals.
3. The contents of d-c circuits.
4. The basic characteristics of d-c series circuits.
5. About Ohm's Law and its uses in d-c series circuits.
6. About power in d-c series circuits.
7. The basic characteristics of d-c parallel circuits.
8. About Ohm's Law and its uses in d-c parallel circuits.
9. About series-parallel circuits.

B. You are learning:

	References:
1. About Kirchhoff's Current Law.	NavPers 10170, pages 10 and 11
2. About Kirchhoff's Voltage Law.	NavPers 10170, pages 11 to 14

C. You will acquire skill in:

1. Applying Kirchhoff's Laws to circuits.

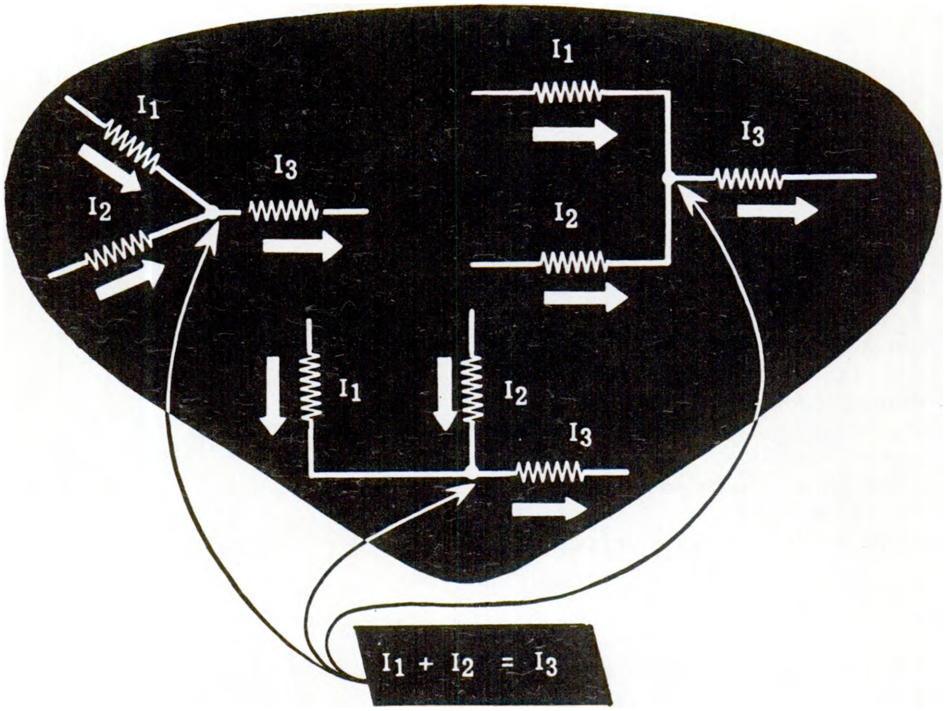
KIRCHHOFF'S CURRENT LAW

You have found out about current flow in the three types of circuits, series, parallel, and series-parallel. You found that the entire circuit current flows through each resistance of a series circuit. In parallel circuits the current divides to flow through more than one path and comes together again after passing through these paths. Series-parallel circuits provide more than one path in some parts of the circuit and only one path in other parts.

Regardless of the circuit connections, you found that the current entering a circuit was exactly the same as that leaving the circuit. This is a direct application of KIRCHHOFF'S FIRST LAW, which states that THE CURRENT ENTERING A JUNCTION IS EQUAL TO THE CURRENT LEAVING THE JUNCTION. The law applies not only to the circuit as a whole but also to every junction within the circuit.

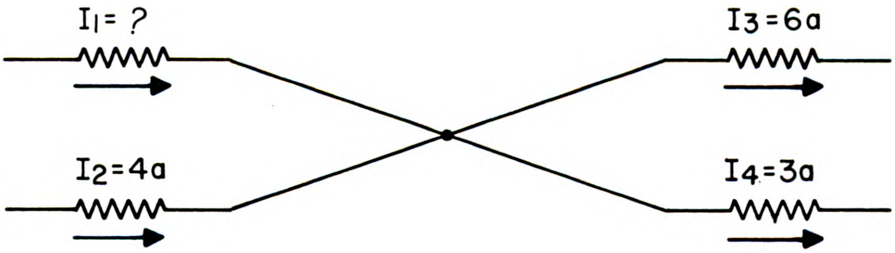
Thus at a junction of three resistances, where two currents--I_1 and I_2--in two of the resistances flow toward the junction and one current--I_3--in the third resistance flows away from the junction, I_3 must equal $I_1 + I_2$.

HOW KIRCHHOFF'S FIRST LAW WORKS



In a complete circuit, the current through each resistance will flow toward a junction at one end of the resistance but away from the junction at the other end of the resistance. To use Kirchhoff's First Law you should indicate the current paths through each resistance of the circuit. Then determine which currents flow toward and which flow away from each junction in the circuit. If certain currents are not known, their value and direction both may be determined by applying Kirchhoff's First Law.

Direction of the unknown current is first determined by comparison of the known currents flowing toward and away from the junction. By adding all the known currents flowing toward the junction and those flowing away from the junction, you can determine



$$I_1 + I_2 = I_3 + I_4$$

$$I_1 + 4 = 6 + 3$$

$$I_1 + 4 = 9$$

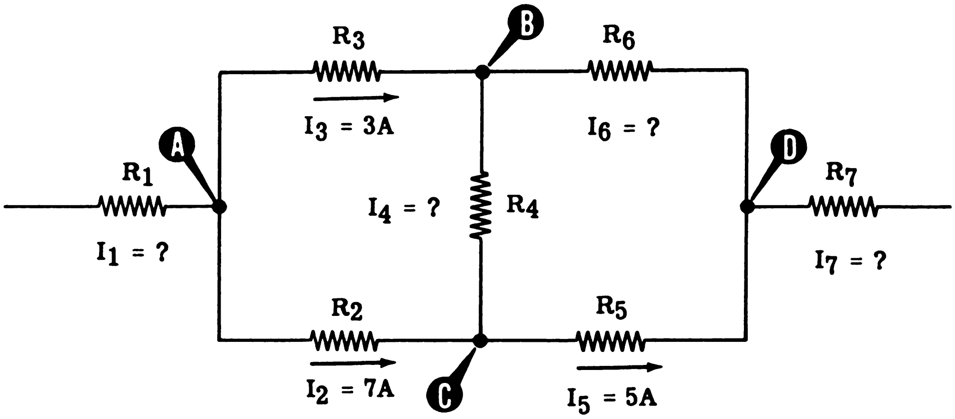
$$I_1 = 9 - 4 = \underline{5a}$$

the direction of the unknown current. At a junction where two currents--I_1 and I_2--enter the junction, and two currents--I_3 and I_4--leave the junction, if I_1 is unknown, it may be found by subtracting I_2 from the sum of I_3 and I_4. Suppose that I_2 is 4 amperes, I_3 is 6 amperes, and I_4 is 3 amperes, then I_1 is equal to 9 amperes ($I_3 + I_4$) minus 4 amperes (I_2), or 5 amperes.

This is how you use Kirchhoff's First Law to find the unknown currents in a circuit.

Suppose your circuit consists of seven resistors--R_1, R_2, R_3, R_4, R_5, R_6, and R_7--connected as shown. If the currents through R_1, R_4, R_6, and R_7 are not known, but the currents and their direction through R_2, R_3, and R_5 are known, the unknown currents may be found by applying Kirchhoff's First Law to the circuit.

In this circuit the current I_2 is 7 amperes flowing toward R_5, the current I_3 is 3 amperes flowing toward R_6, and the current I_5 is 5 amperes flowing toward R_7. Draw the circuit in symbol form designating all currents, with values and direction if known. Identify each junction of two or more resistances with a letter.



Circuit Junctions—A, B, C and D.
Known Currents—I_2, I_3, and I_5
Unknown Currents--I_1, I_4, I_6 and I_7

Find the unknown currents at all junctions where only one current is unknown, later using these new values to find unknown values at other junctions. From the circuit you can see that junctions A and C have only one unknown. Suppose you start by finding the unknown current at junction A.

Of the three currents at junction A--I_1, I_2, and I_3--both I_2 and I_3 are known and flow away from the junction. Then I_1 must flow toward the junction, and its value must equal the sum of I_2 and I_3.

$$I_1 = I_2 + I_3$$
$$I_1 = 7 + 3 = 10 \text{ amperes--toward A.}$$

Next find the unknown current at junction C.

At C, two currents--I_2 and I_5--are known and only I_4 is unknown. Since I_2 flowing toward C is greater than I_5 flowing away from C, the third current I_4 must flow away from C. Also, if the current flowing toward C equals that flowing away, I_2 equals I_4 plus I_5.

$$I_2 = I_4 + I_5$$
$$7 = I_4 + 5$$
$$I_4 = 7 - 5 = 2 \text{ amperes--away from C toward B}$$

Now that the value and direction of I_4 are known, only I_6 is unknown for junction B. You can find the amount and direction of I_6 by applying the law for current at B.

I_3 and I_4 both flow toward B; thus the remaining current I_6 must flow away from B. Also I_6 must equal the sum of I_3 and I_4.

$I_6 = I_3 + I_4$

$I_6 = 3 + 2 = 5$ amperes--away from B, toward D

With I_6 known, only I_7 remains unknown at junction D.

As I_5 and I_6 both flow toward junction D, the current I_7 must flow away from D and is equal to the sum of I_5 and I_6.

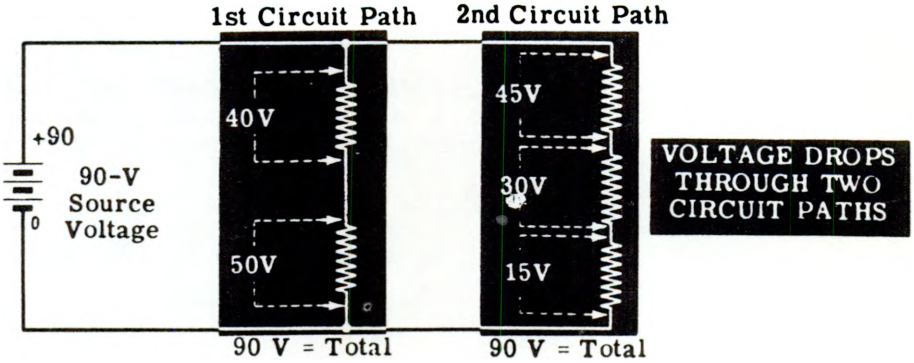
$I_7 = I_5 + I_6$

$I_7 = 5 + 5 = 10$ amperes--away from D

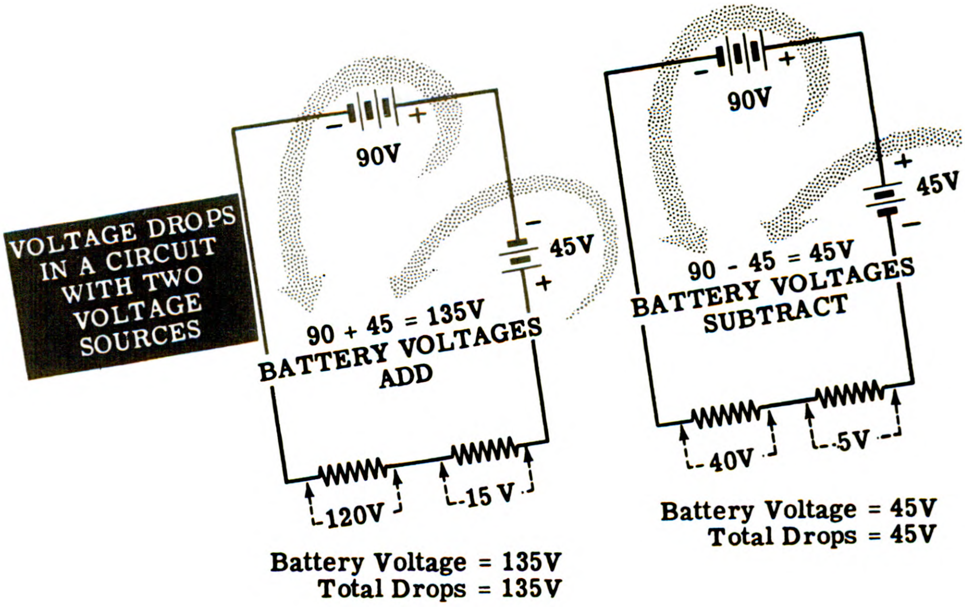
You know now all of the circuit currents and their directions through the various resistances.

KIRCHHOFF'S VOLTAGE LAW

While working with the various types of circuits, you found that for any path between the terminals of a voltage source, the sum of the voltage drops across the resistances in each path equaled the voltage of the source. This is one way of using KIRCHHOFF'S SECOND LAW, which states that THE SUM OF THE VOLTAGE DROPS AROUND A CIRCUIT EQUALS THE VOLTAGE APPLIED ACROSS THE CIRCUIT. In the circuit shown, the voltage drops across each resistance differ, but the sum of those in any one path across the terminals add to equal the battery voltage.



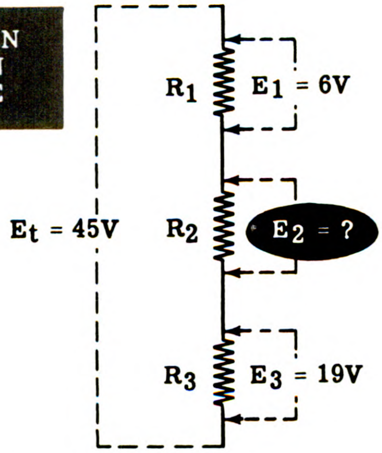
If more than one voltage source is included in the circuit, the actual voltage applied to the circuit is the combined voltage of all voltage sources, and the voltage drops will be equal to this combined voltage. The combined voltage will depend on whether the voltages combine to add or subtract. For example, if two batteries are used in the same circuit, they may be connected to either aid or oppose each other. In either case, the total voltage drops across the circuit resistances will equal the sum or the difference of the batteries.


VOLTAGE DROPS IN A CIRCUIT WITH TWO VOLTAGE SOURCES

Whenever all but one of the voltage drops are known in a path between two junctions, the unknown voltage can be determined by applying Kirchhoff's Second Law if the voltage between the junctions is known. The junctions may be the terminals of a voltage source or they may be two junctions within the circuit itself.

If three resistors--R_1, R_2, and R_3--are connected in series across a known voltage of 45 volts, and the voltage drops of R_1 and R_3 are 6 and 9 volts respectively, the voltage drop across R_2 is found by applying the law for circuit voltages, Kirchhoff's Second Law.

FINDING AN UNKNOWN VOLTAGE



Finding E_2

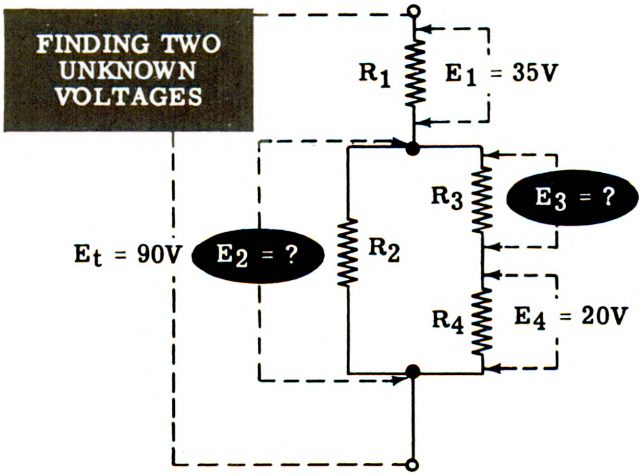
$E_1 + E_2 + E_3 = E_t$

$6V + E_2 + 19V = 45V$

$E_2 + 25V = 45V$

Then $E_2 = 20V$

Unknown voltages within a complex circuit are found by first finding the voltage across each branch of the circuit, then, by applying the law, finding the voltage drops across each resistance in the various branches. For series-parallel circuits, the voltage across parallel parts of the circuit is used as the total voltage across the various resistances within that part of the circuit. To find the unknown voltages in the series-parallel circuit shown, the law for voltages is applied to each path across the current independently.



Finding E_2

$E_1 + E_2 = E_t$

$35V + E_2 = 90V$

Then $E_2 = 55V$

Finding E_3

$E_3 + E_4 = E_2$

$E_3 + 20V = 55V$

Then $E_3 = 35V$

Kirchhoff's Laws are useful not only for simplifying complex circuits, but also for finding unknown values in a part of a circuit, without the necessity of actually measuring the unknown quantities with meters. This often saves time, since current measurement requires opening the circuit to insert an ammeter, and resistance measurements require that the part of the circuit to be measured be disconnected from the rest of the circuit and from any source of voltage.

JOB SHEET NO. 19

1. a. State Kirchhoff's Current Law.
   b. Draw a simple series-parallel circuit showing direction of current flow to explain Kirchhoff's Current Law.

2. State Kirchhoff's Voltage Law.

3. In the following circuit solve for the unknown values listed.

Given:

E_t = 120 v d-c

R_t = 10 ohms

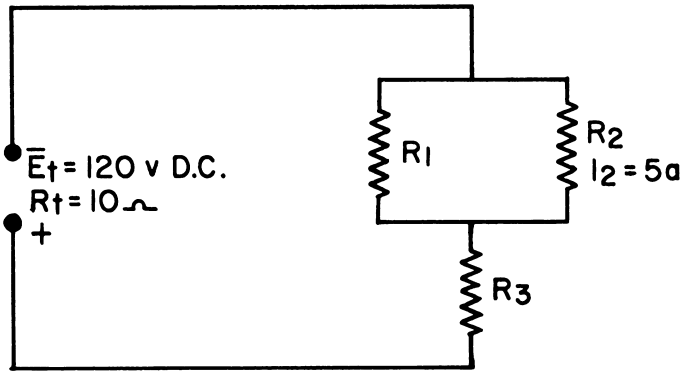
I_t = 5 a

Find:

I_1 = ________

I_3 = ________

I_t = ________



4. In the following circuit solve for the unknown values listed.

Given:

R_1 = 500 ohms

R_2 = 125 ohms

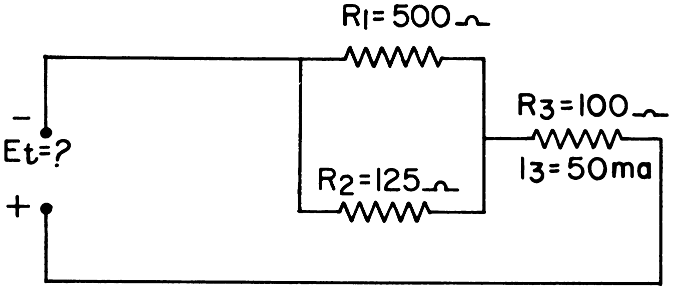
R_3 = 100 ohms

I_3 = 50 ma

Find:

I_1 = ________

I_2 = ________



Note that R_1 is four times greater than R_2. What is the relationship of I_1 to I_2?

5. In the following circuit solve for the unknown values listed.

Given:

E_t = 60 v d-c

R_3 = 500 ohms

I_3 = 20 ma

R_4 = 400 ohms

I_4 = 50 ma

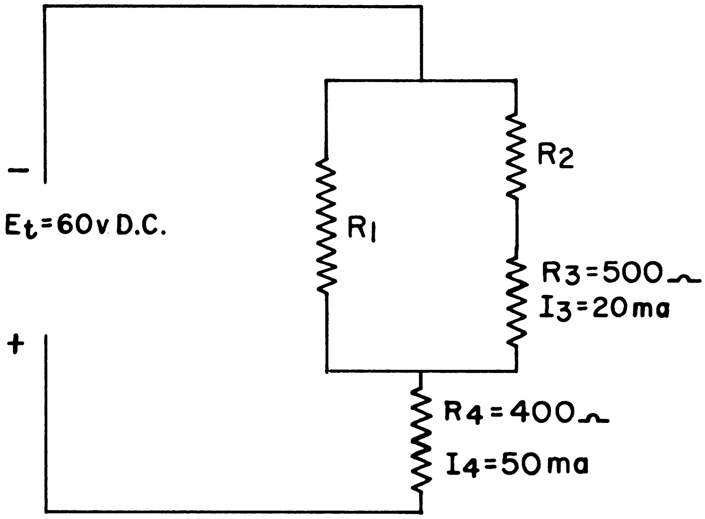
Find:

E_1 = ________

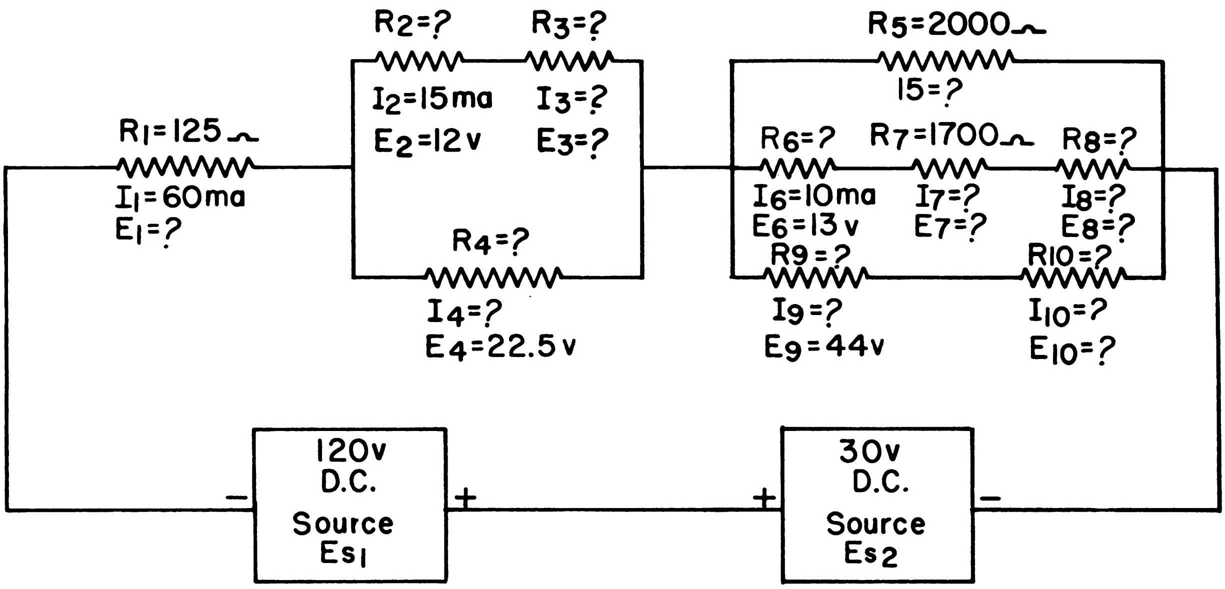
E_2 = ________

E_3 = ________

E_4 = ________



6. In the following circuit solve for the unknown values listed.



Given:

E_{s1} = -120 v
E_{s2} = -30 v
R_1 = 125 ohms
I_1 = 60 ma
E_2 = 12 v
I_2 = 15 ma
E_4 = 22.5 v
R_5 = 2000 ohms
I_6 = 10 ma
E_6 = 13 v
R_7 = 1700 ohms
E_9 = 44 v

Find:

E_s = ________
E_1 = ________
R_2 = ________
E_3 = ________
I_3 = ________
R_3 = ________
I_4 = ________
R_4 = ________
E_5 = ________
I_5 = ________
R_6 = ________
I_7 = ________

E_7 = ________
I_8 = ________
E_8 = ________
R_8 = ________
I_9 = ________
R_9 = ________
E_{10} = ________
I_{10} = ________
R_{10} = ________
R_t = ________
P_t = ________

SECTION IV

ALTERNATING CURRENT ELECTRICITY

Topic No.	Topic Title	Sheet
1.	What Alternating current is	IV-1-1
2.	Resistance in Alternating Current Circuits	IV-2-1
3.	Inductance and Power in Alternating Current Circuits	IV-3-1
4.	Capacitance in Alternating Current Circuits	IV-4-1
5.	Capacitors and Capacitive Reactance	IV-5-1
6.	Impedance in Alternating Current Circuits	IV-6-1

SECTION IV

TOPIC 1

WHAT ALTERNATING CURRENT IS

A. You have learned:	References:
1. About Fire Control in general	
2. About electricity fundamentals	
3. About d-c circuits	
B. You are learning:	
1. What Section IV contains	NavPers 10622-B, pages 169 to 172 and 243
2. To compare a-c to d-c	NavPers 10622-B, pages 239 to 243
3. To generate a sine wave	NavPers 10170, pages 113 to 127
4. Alternating current terms.	NavPers 10622-B, pages 239 to 243

INTRODUCTION TO SECTION IV

Topic 1 consists of a study of ALTERNATING CURRENT ELECTRICITY which constantly changes in amplitude and direction.

Topic 2 takes up the study of resistance and the properties of voltage, current, and power.

The characteristics of an inductive circuit which includes inductance and power will be taken up in topic 3.

The characteristics of capacitance in a circuit will be taken up in topic 4.

A study of capacitors and capacitive reactance will be taken up in topic 5.

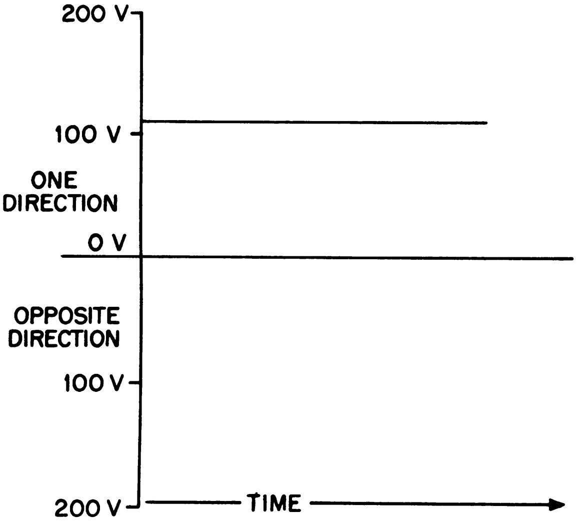
A study of impedance, which is the over-all effect of resistance, inductive reactance, and capacitive reactance will be studies in the final topic.

COMPARISON OF A-C TO D-C

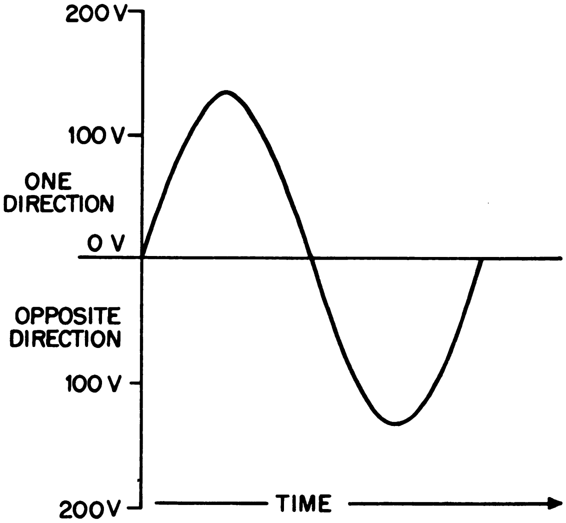
Alternating current reverses its direction of flow at regular intervals, while direct current flows always in one direction.

Direct current may change in amplitude, or pulsate; but pulsating or steady, it always flows in one direction. Alternating current is continuously changing in amplitude. It flows in one direction for a continuous changing in amplitude. It flows in one direction for a definite period of time, reverses itself, and then flows in the opposite direction for a definite period of time.

The following graph should help clear up the differences between a-c and d-c.



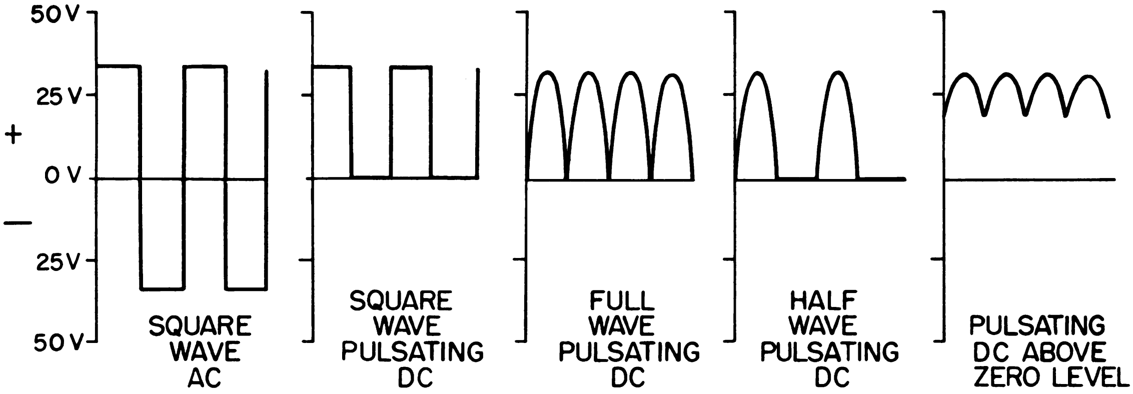
D.C.



A.C.

GENERATING THE SINE WAVE

Waveforms are visual indications of current of voltage compared to time. D-c waveforms appear as straight lines. If a d-c source is reversed at regular intervals, a square wave is the result, which is one form of a-c. A pulsating d-c square wave of current or voltage can be formed by opening and closing a switch in a circuit consisting of a resistor and d-c source.



Waveforms of voltage and current are not always made of straight lines connecting points. In most cases waveforms are curved, representing gradual changes in voltage and current. This is particularly true of pulsating d-c waveforms.

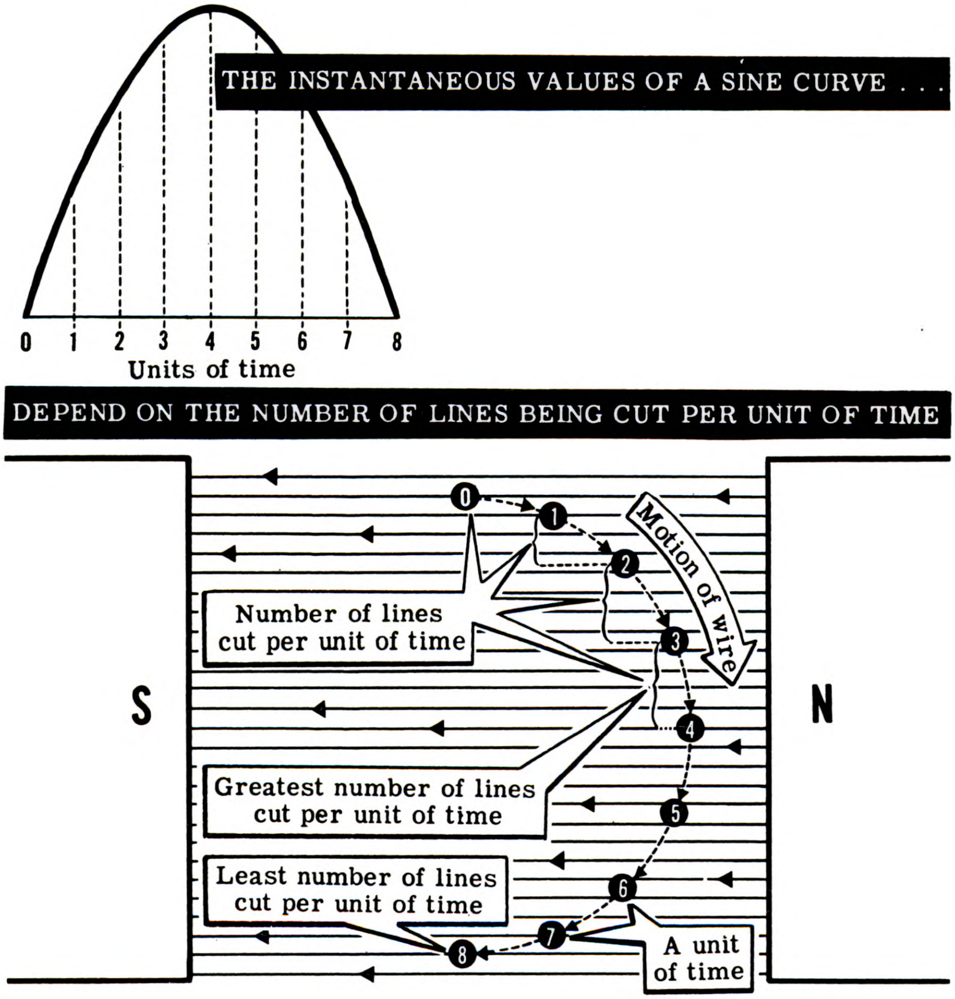
Also, pulsating d-c current and voltage does not always vary between zero and a maximum value, but may vary over any range between these values. The waveform of a d-c generator is pulsating d-c and does not fall to zero but, instead, varies only slightly below the maximum value.

The waveforms of most alternating currents and voltages are curved to represent gradual changes in voltage and current, first increasing then decreasing in value for each direction of current flow. Most of the a-c which you will use is represented by a sine curve. While a-c currents and voltages do not always have waveforms which are exact sine curves, they are normally assumed to have a sine waveform unless otherwise stated.

STUDENT USE THIS SPACE FOR NOTES

The sine waveform for a-c rises gradually to a maximum value, and then falls to zero at the same rate to complete a half cycle. Each point on the curve represents the actual value of current at that moment the "instantaneous value."

When a coil of wire is rotated in a magnetic field, the instantaneous value of current generated depends on the number of lines of force being cut per unit of time. The number of lines cut increases as the coil turns from the zero current position, when the coil is halfway between the poles, toward a maximum current position, when the coil is nearest one of the poles. The number of lines cut then decreases till it becomes zero again when the coil reaches the opposite position between poles. At any moment, the instantaneous value of the current generated depends on the total angle through which the coil has turned. A continuous curve constructed by plotting all of the instantaneous values is a "sine wave."

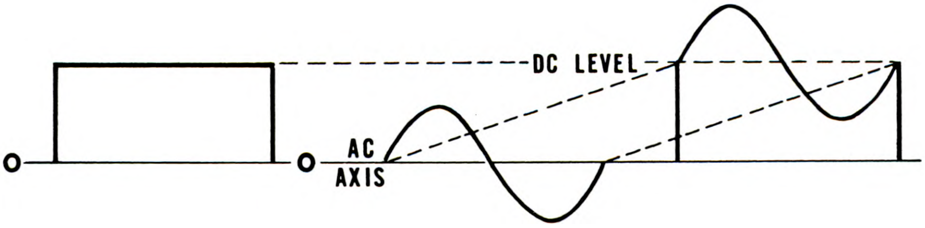


THE INSTANTANEOUS VALUES OF A SINE CURVE . . .

DEPEND ON THE NUMBER OF LINES BEING CUT PER UNIT OF TIME

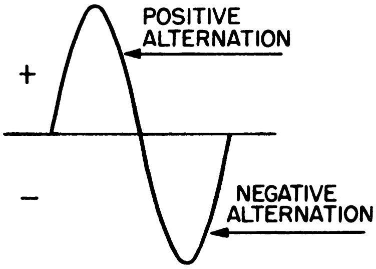
0
1
2
3
4
5
6
7
8
Units of time
S
N
Motion of wire
Number of lines cut per unit of time
Greatest number of lines cut per unit of time
Least number of lines cut per unit of time
A unit of time

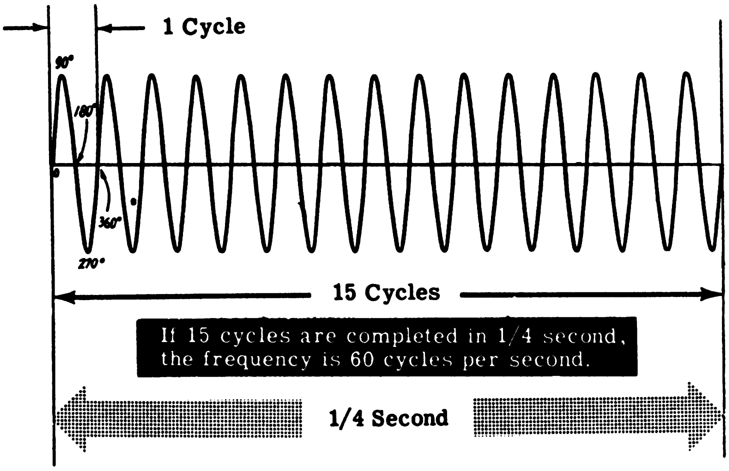
When d-c and a-c voltages are both present in the same circuit, the resulting voltage is a combination of the two voltages. The a-c wave is added to the d-c wave, with the value of the d-c voltage becoming the axis from which the a-c wave moves in each direction. Thus the maximum point of d-c voltage replaces the zero value as the a-c waveforms axis. The resulting waveform is a combination of d-c and a-c and is called "super-imposed a-c," or "pulsating d-c," meaning that the a-c wave is added to or placed over the d-c wave.



DC waveform + AC waveform = Superimposed AC waveform

A cycle of voltage or current is the period of time required to go from zero to positive maximum, to zero, to negative maximum, and again positive alternation being the time the current is flowing in one direction and the negative alternation is the time the current is flowing in the opposite direction. The number of cycles generated per second is the frequency of the current and voltage.





If 15 cycles are completed in 1/4 second, the frequency is 60 cycles per second.

The majority of a-c used in the GFCS Mk 51 is 60 cycle but other frequencies will be encountered, especially in the stabilizing circuits of Power Drive Mark 4. The stabilizing circuits smooth out the operation of the power drives in train and elevation.

ALTERNATING CURRENT TERMS

The MAXIMUM VALUE of a sine wave of current or voltage is the highest value attained in either a negative or positive direction.

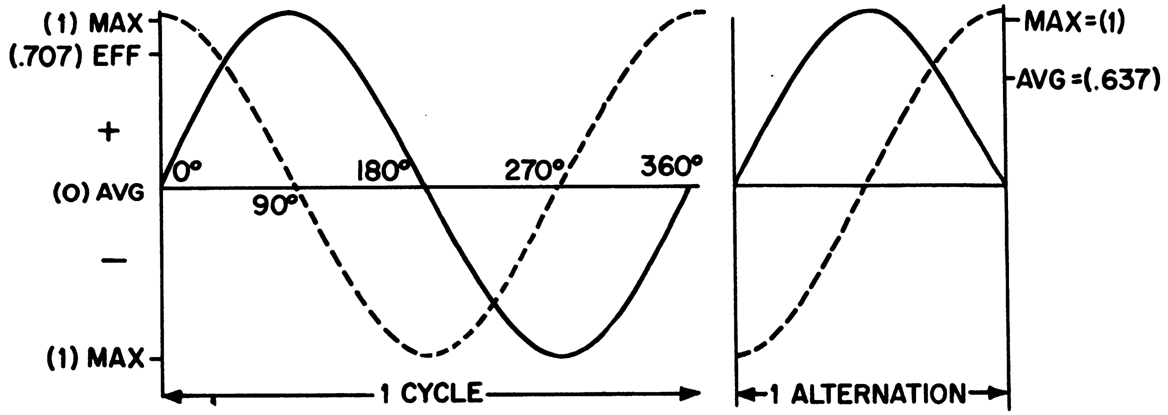
The AVERAGE VALUE of a sine wave is zero.

The AVERAGE VALUE of one alternation is .637 times maximum value.

The EFFECTIVE VALUE of a sine wave of current or voltage is .707 times maximum value. The effective value of a-c has the same HEATING EFFECT as an equal value of d-c. The value indicated on an a-c meter is the effective value of the a-c.

PEAK TO PEAK VALUE is the distance between the negative and positive maximum values.

PHASE RELATIONSHIP is the angular displacement of one sine wave from another in electrical degrees. There are 360 electrical degrees in one cycle, 180 electrical degrees in one alternation; so, ONE ELECTRICAL DEGREE is 1/360 of one cycle.



TWO SINE WAVES DISPLACED BY NINETY DEGREES

TOPIC 2

RESISTANCE IN ALTERNATING CURRENT CIRCUITS

A. You have learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
3. About d-c Circuits.	
4. What a-c is.	
B. You are learning:	
1. The characteristics of resistive a-c circuits.	NavPers 10622-B, page 243
2. About voltage and current in resistive a-c circuits.	
3. About power in resistive a-c circuits.	
C. You will acquire skill in:	
1. Computing power in a resistive a-c circuit.	

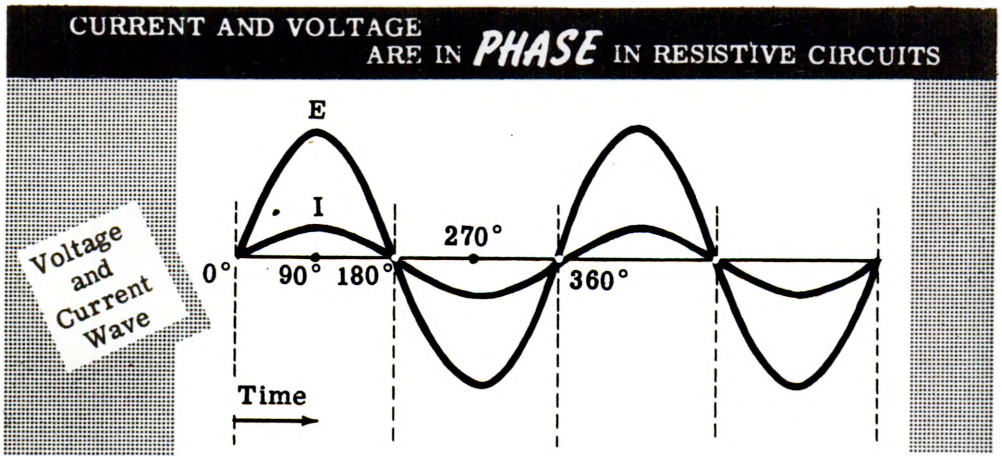
A-C CIRCUITS CONTAINING RESISTANCE ONLY

MANY A-C CIRCUITS CONSIST OF PURE RESISTANCE, AND FOR SUCH CIRCUITS THE SAME RULES AND LAWS APPLY AS FOR D-C CIRCUITS. Pure resistance circuits are made up of electrical devices which contain no inductance or capacitance (you will find out about inductance and capacitance a little later). Devices such as resistors, lamps, and heating elements have negligible inductance or capacitance and for practical purposes are considered to be made up of pure resistance. When only such devices are used in an a-c circuit, Ohm's Law, Kirchhoff's Laws and the circuit rules for voltage, current, and power can be used exactly as in d-c circuits.

In using the circuit laws and rules you must use effective values of a-c voltage and current. Unless otherwise stated, all a-c voltage and current values are given as effective values. Other values such as peak-to-peak voltages must be changed to effective values before using them for circuit computations.

VOLTAGE AND CURRENT IN RESISTIVE A-C CIRCUITS

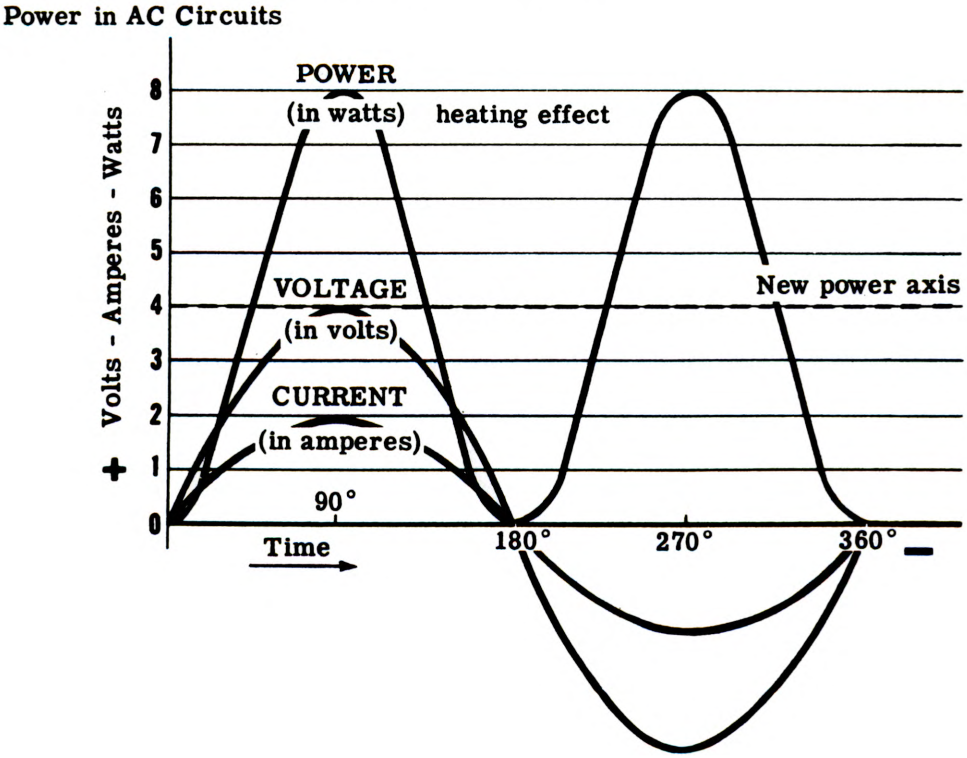
When an a-c voltage is applied across a resistor, the voltage increases to a maximum with one polarity, decreases to zero, increases to a maximum with the opposite polarity and again decreases to zero, to complete a cycle of voltage. The current flow follows the voltage exactly: as the voltage increases the current increases; when the voltage decreases the current decreases; and at the moment the voltage changes polarity, the current flow reverses its direction. Because of this, the voltage and current waves are said to be "in phase."



Sine waves of voltages or currents are in phase whenever they are of the same frequency and pass through zero simultaneously, both going in the same direction. The amplitude of two voltage waves or two current waves which are in phase are not necessarily equal, however. In the case of inphase current and voltage waves, they are seldom equal since they are measured in different units.

POWER IN RESISTIVE A-C CIRCUITS

The power used in an a-c circuit is the average of all the instantaneous values of power for a complete cycle. To find the power, all of the corresponding instantaneous values of voltage and current are multiplied together to find the instantaneous values of power, which are then plotted for the corresponding time to form a power curve. The average of this power curve is the actual power used.



A-C POWER WAVEFORM

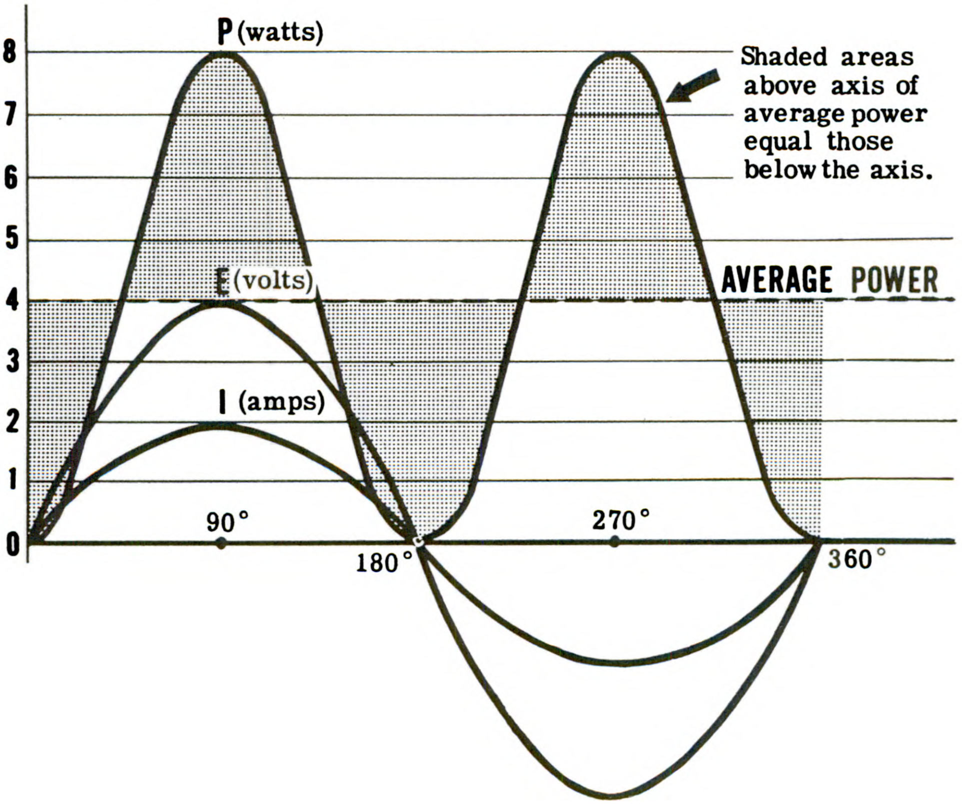
For in-phase voltage and current waves, all of the instantaneous powers are above the zero axis and the entire power curve is above the zero axis. This is due to the fact that whenever two positive values are multiplied together the result is positive, and whenever two negative values are multiplied together the result is also positive. Thus, during the first half cycle of E and I, the power curve increases in a positive direction from zero to a maximum and then decreases to zero just as the E and I waves do. During the second half cycle, the power curve again increases in a positive direction from zero to maximum and then decreases to zero while E and I both increase and decrease in the negative direction. Notice that if a new axis is drawn through the power wave, halfway between its maximum and minimum values, the power wave frequency is twice that of the voltage and current waves.

When two numbers--each being less than 1--are multiplied together, the result is a smaller number than either of the original numbers--for example, 0.5V x 0.5A = 0.25W. For that reason, some or all of the instantaneous values of a power wave may be less than those for the circuit current and voltage waves.

A line drawn through the power wave exactly halfway between its maximum and minimum values is the axis of the power wave. This axis represents the average value of power in a resistive circuit, since the shaded areas above the axis are exactly equal in area to those below the axis. Average power is the actual power used in an a-c circuit.

Since all the values of power are positive for a-c circuits consisting only of resistance, the power wave axis and the average power for such circuits is equal to exactly one-half the maximum, positive, instantaneous power value. This value can also be found by multiplying the effective values of E and I together. This applies to a-c circuits containing the resistance only, since a-c circuits containing inductance or capacitance may have negative instantaneous power values.

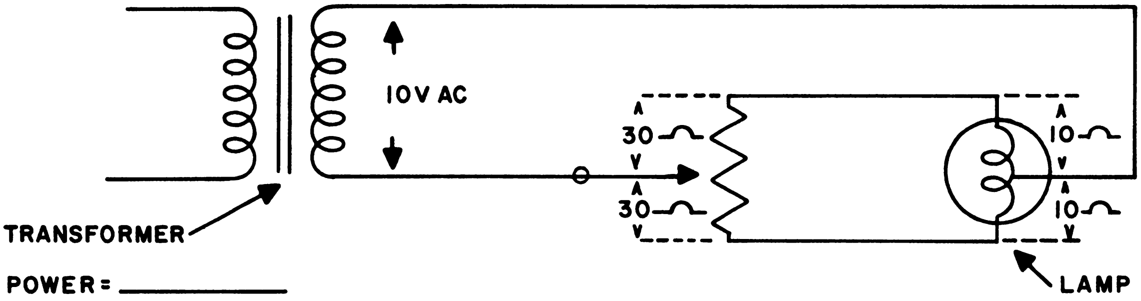
IN A-C CIRCUITS WITH RESISTANCE ONLY



JOB SHEET NO. 20

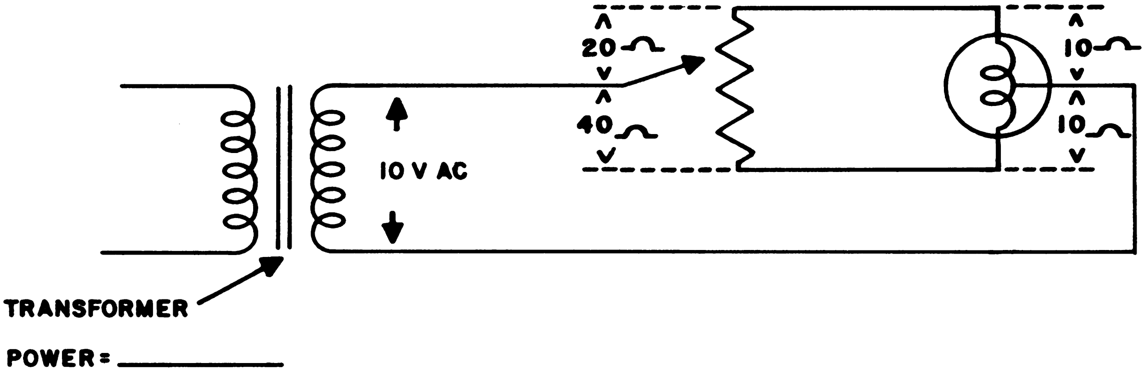
Fill in the blank spaces with the proper word, or words, and solve the problems for the values required.

1. The rules and laws of d-c also apply to ____________________ a-c circuits.
2. In resistive a-c circuits, current and voltage are ________________ phase.
3. The power used in an a-c circuit is the _________________ of all the instantaneous values of power for a complete cycle.
4. Power used in an a-c resistive circuit is equal to __________________________ current times ____________________.
5. The following diagram shows the reticle lamp circuit of Gun Sight Mk 14 with the brightness control at the DIMMED position. The resistance (hot) of each filament in the reticle lamp is approximately 10 ohms. Find the power consumed by the circuit.



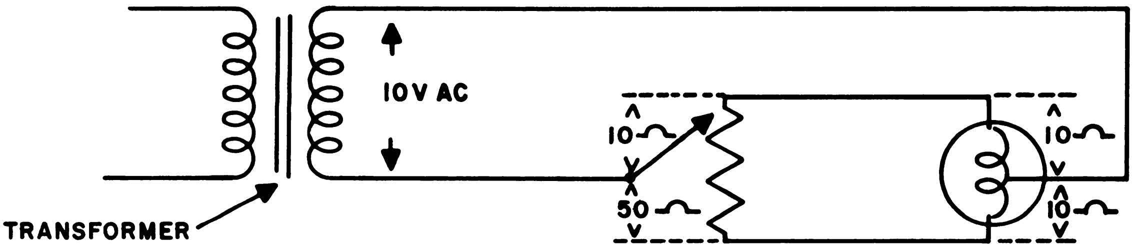
Power = __________

6. The following diagram shows the same circuit with the brightness control adjusted to give more illumination. Find the power consumed by the circuit.



Power = __________

7. The following diagram shows the same circuit with the brightness control adjusted to give still more illumination. Find the power consumed by the circuit.



POWER = ____________

Power= ____________

8. As the brightness control was adjusted to give more illumination, the total resistance ______________________________, and the power ____________________________.

SECTION IV

TOPIC 3

INDUCTANCE AND POWER IN ALTERNATING CURRENT CIRCUITS

A. You have learned:	References:
1. About Fire Control in general	
2. About electricity fundamentals	
3. About d-c circuits	
4. What a-c is	
5. About resistive a-c circuits	
B. You are learning:	
1. About inductance and its effects	NavPers 10622-B, pages 244 to 249 NavPers 10170, pages 149 to 154
2. Factors affecting inductance	NavPers 10622-B, pages 244 to 248 NavPers 10170, pages 149 to 152
3. About self inductance and mutual inductance	NavPers 10622-B, pages 244 to 248 NavPers 10170, pages 149 to 152
4. About inductive reactance	NavPers 10622-B, pages 244 to 248 NavPers 10170, pages 153 and 154
5. About power in an inductive circuit	NavPers 10622-B, pages 244 to 248 NavPers 10170, pages 168 to 170
C. You will acquire skill in:	
1. Solving problems in inductive circuits	NavPers 10622-B, pages 248 and 249 NavPers 10170, pages 154 to 168

INDUCTANCE AND ITS EFFECTS

Inductance is the property of a circuit which opposes any change in current flow and is symbolized by the letter "L."

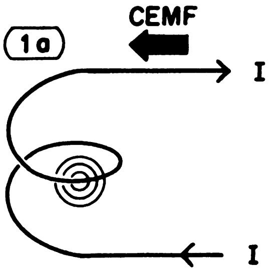
Current flow through a conductor generates a magnetic field around the conductor. This magnetic field builds up as current increases. As current reaches a constant value, the magnetic lines of flux about the conductor remain stationary and, as current decreases, the lines of force collapse back into the conductor.

As current increases in a coil, the expanding magnetic field cuts adjacent turns of the coil, inducing a counter-emf in the coil. The counter-emf generated by the magnetic field cutting turns of a coil opposes source voltage and thereby resists any change in current.

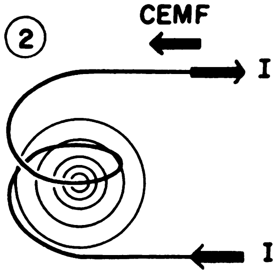
When current decreases in a coil, the contracting magnetic field aids the source voltage and tends to keep the current flowing. It is actually this expansion and contraction of the magnetic field as the current varies which causes the effect known as inductance. Thus, inductance, the effect of counter-emf, opposes any change in current flow, whether it is an increase or decrease, slowing down the rate at which the change occurs.

The following sequence of sketches is designed to help you visualize what happens in an a-c current-carrying coil for one complete cycle. The moving relationship of the flux field and cemf to a changing current is illustrated.

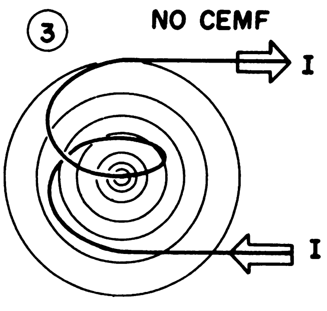
Each individual sketch should be compared to the sine wave of current and cemf.



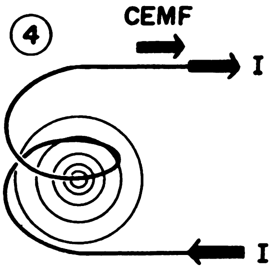
SMALL I - INC.
HIGH RATE OF CHANGE OF I
MAX. L O F CUTTING COIL
MAX. CEMF OPPOSING



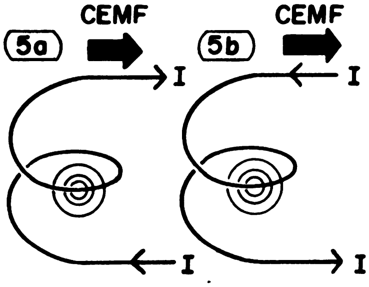
LARGE I - INC.
LOW RATE OF CHANGE OF I
FEW L O F CUTTING COIL
LOW CEMF OPPOSING



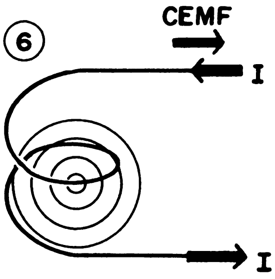
MAX. I - STEADY
ZERO RATE OF CHANGE OF I
NO L O F CUTTING COIL
NO CEMF



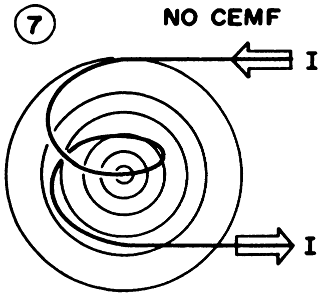
LARGE I - DEC.
LOW RATE OF CHANGE OF I
FEW LOF CUTTING COIL
LOW CEMF - AIDING



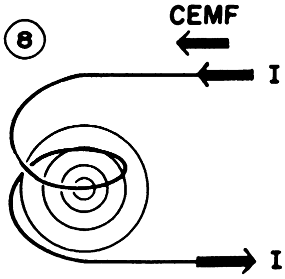
DEC. I - I REVERES - INC. I
HIGH RATE OF CHANGE OF I
MAX. LOF CUTTING COIL
MAX. CEMF
AIDING ——— OPPOSING



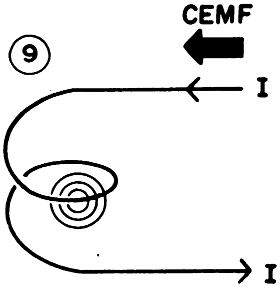
LARGE I - INC.
LOW RATE OF CHANGE OF I
FEW LOF CUTTING COIL
LOW CEMF - OPPOSING



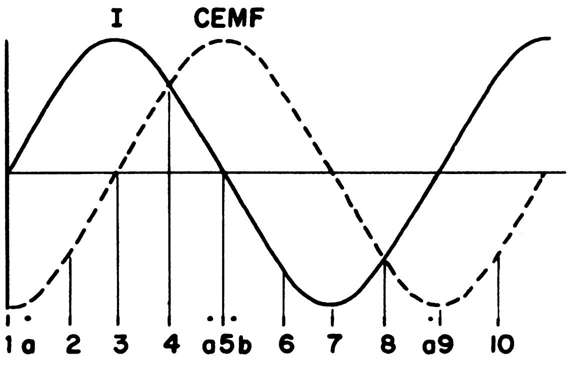
MAX. I - STEADY
ZERO RATE OF CHANGE OF I
NO LOF CUTTING COIL
NO CEMF



LARGE I - DEC.
LOW RATE OF CHANGE OF I
FEW LOF CUTTING COIL
LOW CEMF - AIDING



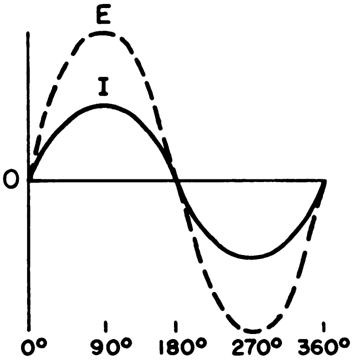
SMALL I - DEC.
HIGH RATE OF CHANGE OF I
MAX. LOF CUTTING COIL
MAX. CEMF - AIDING



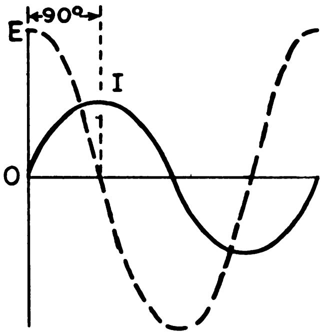
When an inductive circuit is opened, the current drops rapidly toward zero and the field also collapses at a very high rate. The rapidly collapsing field generates a very high counter-emf, which not only opposes the change in current but also causes an arc across the switch or contacts to maintain the current flow. Although only momentary, the counter-emf caused by this rapid field collapse is very high, sometimes many times that of original source voltage. This action is often used to advantage in special types of equipment to obtain very high voltages, or in the mount drive motors, this action is used in dynamic braking. Disadvantages of arcing caused by the collapsing field are burned switches and relay contacts.

In a pure inductive circuit, the voltage leads the current by 90°

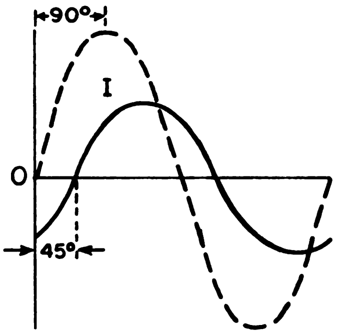
In a circuit containing both resistance and inductance, the voltage would lead the current by a phase angle of from zero to ninety degrees, depending on the ratio of Rtol.



PURE RESISTIVE CKT.
E + I IN PHASE



PURE INDUCTIVE CKT.
E LEADS I BY 90°



RESISTIVE & INDUCTIVE CKT.
E LEADS I LESS THAN 90°

FACTORS AFFECTING INDUCTANCE

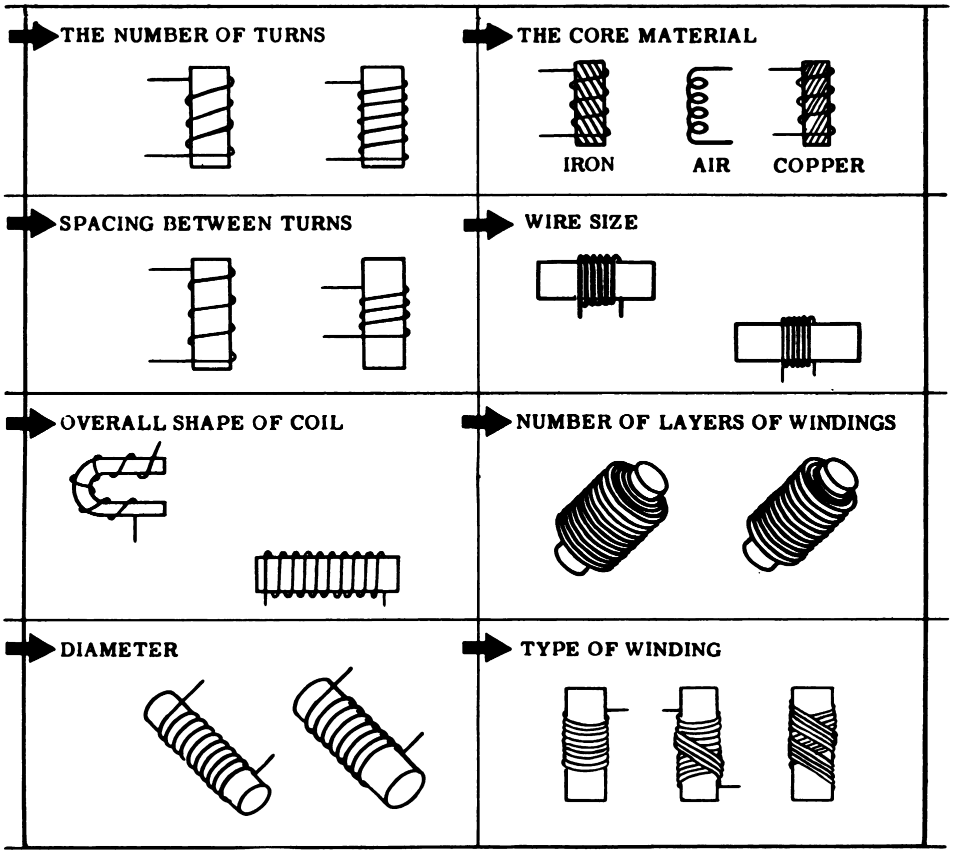
There are eight factors that control inductance and they are usually fixed.

An increase in number of turns of wire increases the inductance. A cemf is generated even in a straight piece of wire, by the action of the magnetic field expanding outward from the center of the wire or collapsing inward to the wire center. The greater the number of adjacent turns of wire cut across by the expanding field, the greater the cemf generated--so that a coil of wire having many turns has a high inductance.

An iron core inserted in a coil increases the inductance because it provides a better path for magnetic lines of force than does air. All the coils in the power drive are of the iron core type.

There are several other factors important in determining the amount of inductance of a coil. Some of them are: the spacing between the turns, coil diameter, kind of material around the inside of the coil, the wire size, number of layers of wire, type of coil winding, and over-all shape of the coil.

Inductance can be measured only with special laboratory instruments, and depends entirely on the physical construction of the coil.



INDUCTANCE DEPENDS ON PHYSICAL CHARACTERISTICS

SELF AND MUTUAL INDUCTANCE

Self inductance is caused by a varying field cutting its own conductor. As the varying field cuts its own conductor, a cemf is induced in the conductor. In self induction, the field must vary. A conductor can cut its own field only when its field varies in strength.

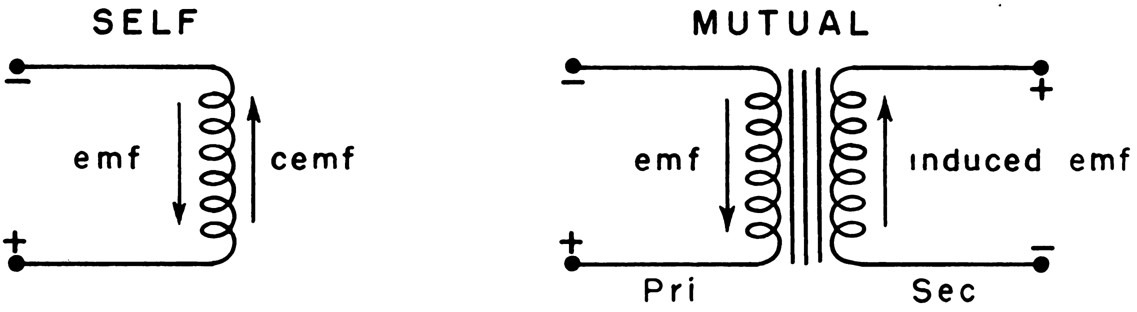
If there were a purely inductive circuit, the self-induced voltage would be equal in amplitude and opposite in phase to the applied voltage. A purely inductive circuit is impossible because there is some resistance in every circuit.

In a circuit containing inductance, the self-induced voltage reacts with the applied voltage to reduce current and to cause current to be out-of-phase with the applied voltage.

Mutual induction is caused by the field of one conductor cutting another conductor. This relative motion between the field and conductor can be brought about by moving a conductor through a magnetic field or by causing the field to cut the conductor.

The coil which originates the flux field is called the primary and the coil which has a voltage induced in it is called the secondary.

INDUCTION



INDUCTIVE REACTANCE

Inductive reactance is the opposition to current flow offered by the inductance of a circuit. As you know, inductance affects current flow only while the current is changing, since the current change generates a counter-emf. For direct current the effect of inductance is noticeable only when the current is turned on and off but, since alternating current is continuously changing, a continuous counter-emf is generated.

An inductive circuit would affect a-c voltage and current as shown below. The current rises as the voltage rises, but the delay due to inductance prevents the current from ever reaching its maximum d-c value before the voltage reverses polarity and changes the direction of current flow. Thus, in a circuit containing inductance, the maximum current will be much greater for d-c than for a-c.

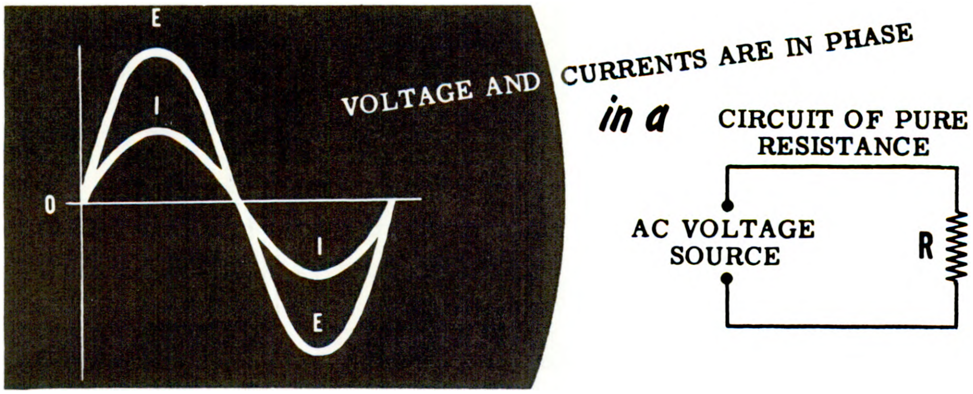
If the frequency of the a-c wave is low, the current will have time to reach a higher value before the polarity is reversed than if the frequency is high. Thus, the higher the frequency, the lower the circuit current through an inductive circuit. Frequency, then, affects the opposition to current flow as does circuit inductance. For that reason, inductive reactance--opposition to current flow offered by an inductance--depends on frequency and inductance. The formula used to obtain inductive reactance is:

$$X_L = 2\pi fL$$

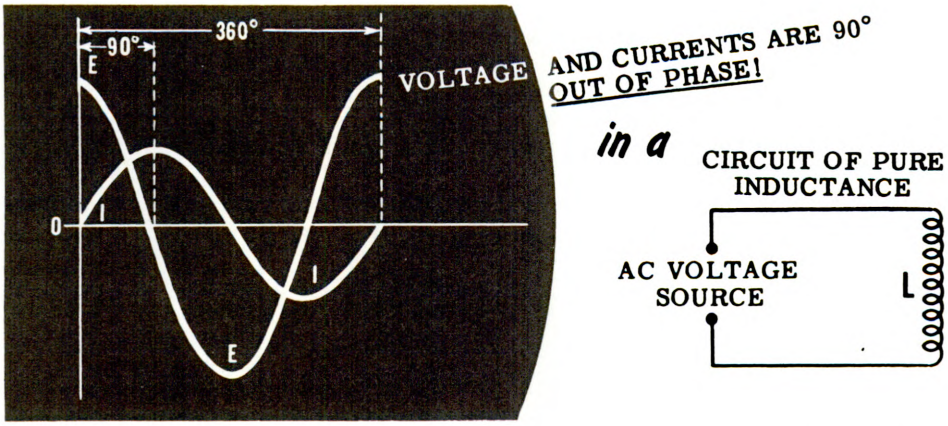
In this formula X_L is inductive reactance, $\underline{f}$ is frequency in cycles per second, $\underline{L}$ is the inductance in henries, and 2π is a constant number (6.28) representing one complete cycle. Since X_L represents opposition to current flow, it is expressed in ohms.

Actually, the circuit current does not begin to rise at the same time the voltage begins to rise. The current is delayed to an extent depending on the amount of inductance in the circuit as compared to the resistance.

If an a-c circuit has only pure resistance, the current rises and falls at exactly the same time as the voltage, and the two waves are said to be "in-phase" with each other.

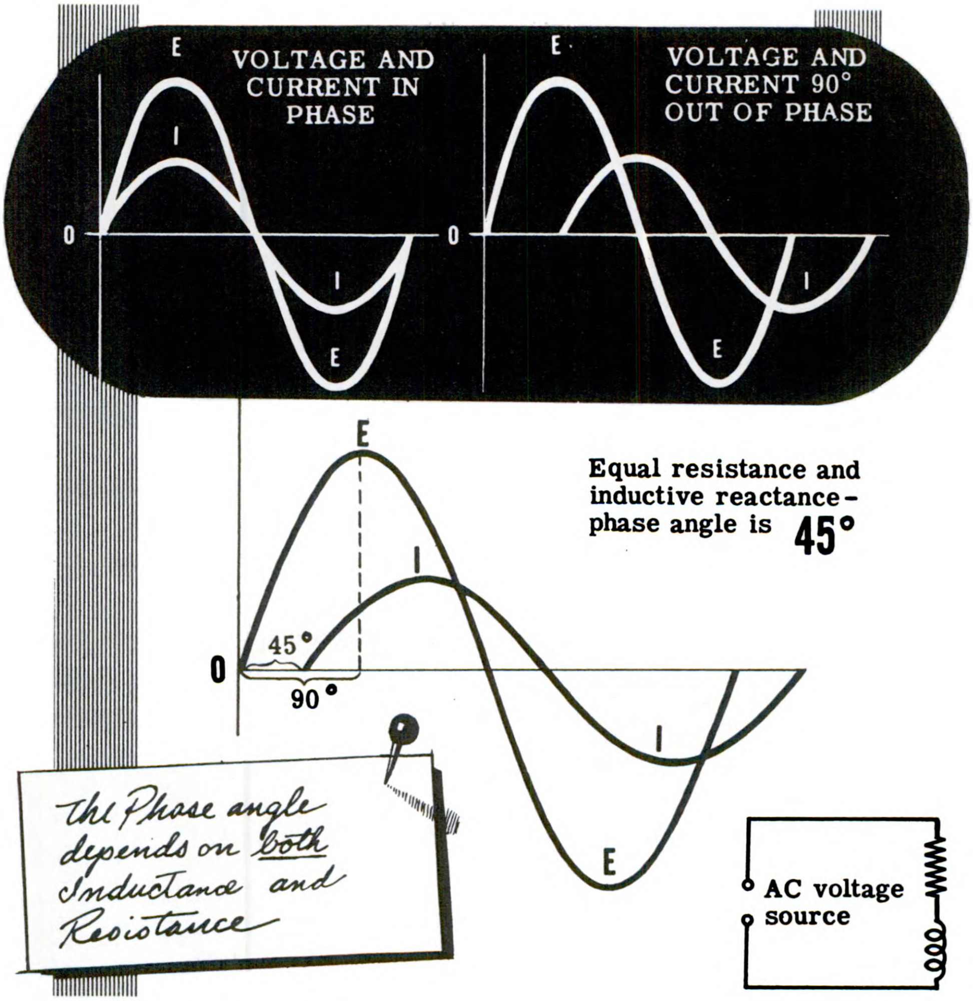


With a theoretical circuit of pure inductance and no resistance, the current will not begin to flow until the voltage has reached its maximum value, and the current wave then rises while the voltage falls to zero. At the moment the voltage reaches zero the current starts to drop toward zero, but the collapsing field delays the current drop until the voltage reaches its maximum value in the opposite polarity. This continues as long as voltage is applied to the circuit, with voltage wave reaching its maximum value a quarter cycle before the current wave on each half cycle. A complete cycle of an a-c wave is considered to be 360 degrees, represented by the emf generated in a wire rotated once around in a complete circle between two opposite magnetic poles. A quarter cycle, then, is 90 degrees; and in a purely inductive circuit the voltage wave leads the current by 90 degrees or, in opposite terms, the current wave lags the voltage by 90 degrees.


360°
90°
E
0
I
I
E
VOLTAGE AND CURRENTS ARE 90° OUT OF PHASE!
in a
CIRCUIT OF PURE INDUCTANCE
AC VOLTAGE SOURCE
L

In a circuit containing both inductive reactance and resistance, the a-c current wave will lag the voltage wave by an amount between zero degrees and 90 degrees; or, stated otherwise, it will lag somewhere between in-phase and 90 degrees out-of-phase. The exact amount of lag depends on the ratio of circuit resistance to inductance--the greater the resistance compared to the inductance, the nearer the two waves are to being in-phase; and the lower the resistance compared to the inductance, the nearer the waves are to being a full quarter cycle (90 degrees) out-of-phase.

When stated in degrees the current lag is called the "phase angle." If the phase angle between the voltage and the current is 45 degrees lagging, it means that the current wave is lagging the voltage wave by 45 degrees. Since this is halfway between zero degrees--the phase angle for a pure resistive circuit, and 90 degrees--the phase angle for a pure inductive circuit, the resistance and the inductance reactance must be equal, with each having an equal effect on the current flow.



POWER IN AN INDUCTIVE CIRCUIT

In a theoretical circuit containing only pure inductance the current lags the voltage by 90 degrees. To determine the power wave for such a circuit, all of the corresponding instantaneous values of voltage and current are multiplied together to find the instantaneous values of power, which are then plotted to form the power curve.

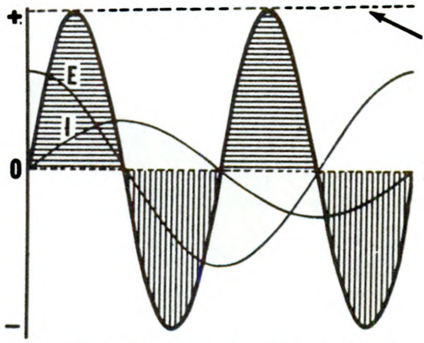
As you already know, the power curve for in-phase voltages and currents is entirely above the zero axis, since the result is positive when either two positive numbers are multiplied together or two negative numbers are multiplied together. When a negative number is multiplied by a positive number, however, the result is a negative number. Thus, in computing instantaneous values of power when the current and voltage are not in-phase, some of the values are negative. If the phase difference is 90 degrees, as in the case of a theoretical circuit containing only pure inductance, half the instantaneous values of power are positive and half are negative, as shown below. For such a circuit the voltage and current axis is also the power wave axis, and the frequency of the power wave is twice that of the current and voltage waves.

That portion of a power wave which is above the zero axis is called "positive power" and that which is below the axis is called "negative power." Positive power represents power furnished to the circuit by the power source, while negative power represents power the circuit returns to the power source.

In the case of a pure inductive circuit the positive power furnished to the circuit causes a field to build up. When this field collapses, it returns an equal amount of power to the power source. Since no power is used for heat or light in a circuit containing only pure inductance (if it were possible to have such a circuit), no actual power would be used even though the current flow were large. The actual power used in any circuit is found by subtracting the negative power from the positive power.

Any practical inductive circuit contains some resistance, and since the phase angle depends on the ratio between the inductive reactance and the resistance, it is always less than 90 degrees. For phase angles of less than 90 degrees, the amount of positive power always exceeds the negative power, with the difference between the two representing the actual power used in overcoming the circuit resistance. For example, if your circuit contains equal amounts of inductive reactance and resistance, the phase angle is 45 degrees and the positive power exceeds the negative power, as shown below.

90° Phase Angle (Negative power equals the positive power)

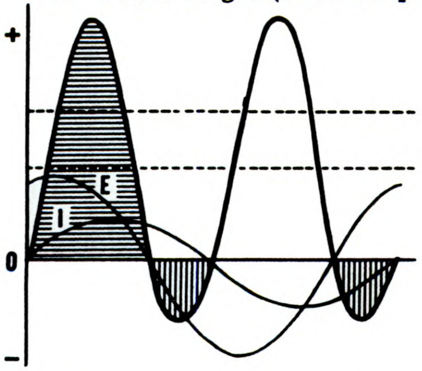


Apparent power E x 1 = V. A.

Power wave axis—True power is zero

$$\text{P. F.} = \frac{I^2R \text{ or } \frac{E^2}{R}}{\text{V. A.}} = 0\% \text{ at } 90^\circ$$

45° Phase Angle (Positive power exceeds negative power)



Apparent power Ex1 = V. A.

Power wave axis—True power used (I²R)

$$\text{P. F.} = \frac{I^2R}{\text{V. A.}} = 70\% \text{ at } 45^\circ$$

DECREASING THE PHASE ANGLE INCREASES THE TRUE POWER

The average value of actual power, called "true power," is represented by an axis drawn through the power wave halfway between the opposite maximum values of the wave. As the phase angle increases, this axis moves nearer to the axis for voltage and current. In a-c circuits the apparent power is found by multiplying the voltage and current just as in d-c circuits: (Apparent power = Voltage x Current).

Apparent power and true power for an a-c circuit are equal only when the circuit consists entirely of pure resistance. The difference between apparent and true power is sometimes called "wattless power" since it does not produce heat or light but does require current flow in a circuit.

JOB SHEET NO. 21

1. The unit of inductance is the__________and it is symbolized by the letter__________.

2. Inductance opposes any change in________________.

3. In a pure inductive circuit, the voltage leads the current by________________.

4. Give eight factors that affect inductance.

   a.____

   b.____

   c.____

   d.____

   e.____

   f.____

   g.____

   h.____

5. Sketch sine waves of voltage leading current by 60 degrees.

6. Self inductance is caused by____

   ____.

7. List six examples of mutual induction in the power drive.

   a.____________________.   d.____________________.

   b.____________________.   e.____________________.

   c.____________________.   f.____________________.

8. P5 in the elevation amplifier has an X_L of 817 ohms. Find the following values with the aid of figure 104 in OP 821A.

   a. f =____________________.   b. I =____________________.

9. The inductance of T6 in the elevation amplifier is 10h and frequency is 120 cycles. What is the value of X_L?____

   ____________________.

10. Actual power in a pure inductive circuit is____________________.

11. ____________________power is returned to the source by an inductive circuit.

12. Voltage multiplied by current equals____________________power in an a-c circuit.

13. In what type of a-c circuit is true power equal to apparent power?

    ____.

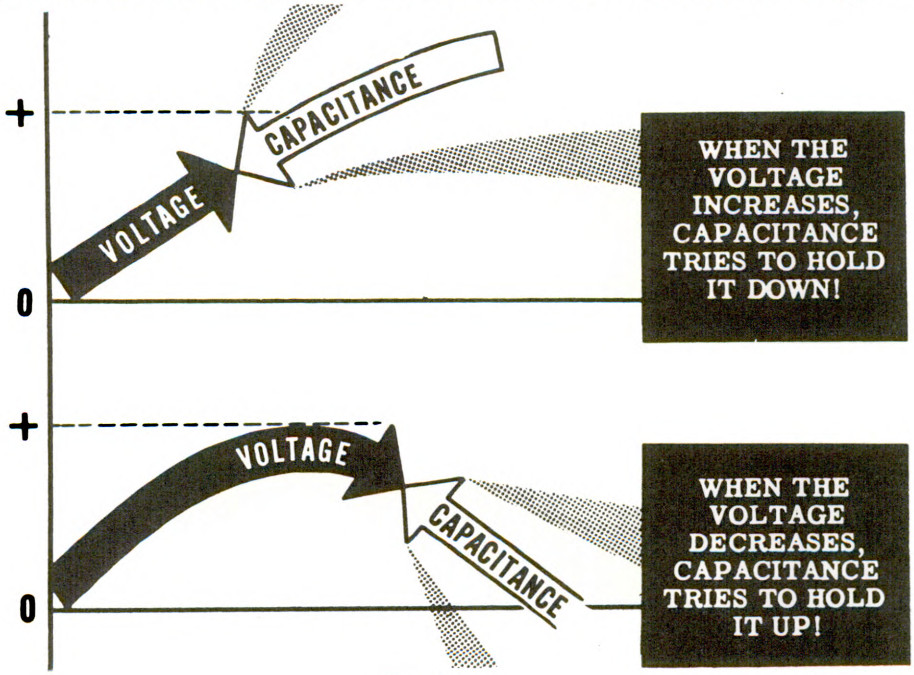
TOPIC 4

CAPACITANCE IN A-C CIRCUITS

A. You have learned:	References:
1. About Fire Control in general.	
2. About electricity fundamentals.	
3. About d-c circuits.	
4. What a-c is.	
5. About resistive a-c circuits.	
6. About inductance and power in a-c circuits.	
B. You are learning:	
1. About capacitance and its effect.	NavPers 10170, page 174
2. How capacitors are charged and discharged.	NavPers 10622-B, pages 249-253
3. Units and symbols of capacitance.	NavPers 10170, page 174
C. You will acquire skill in:	
1. Converting the units of capacitance.	

CAPACITANCE

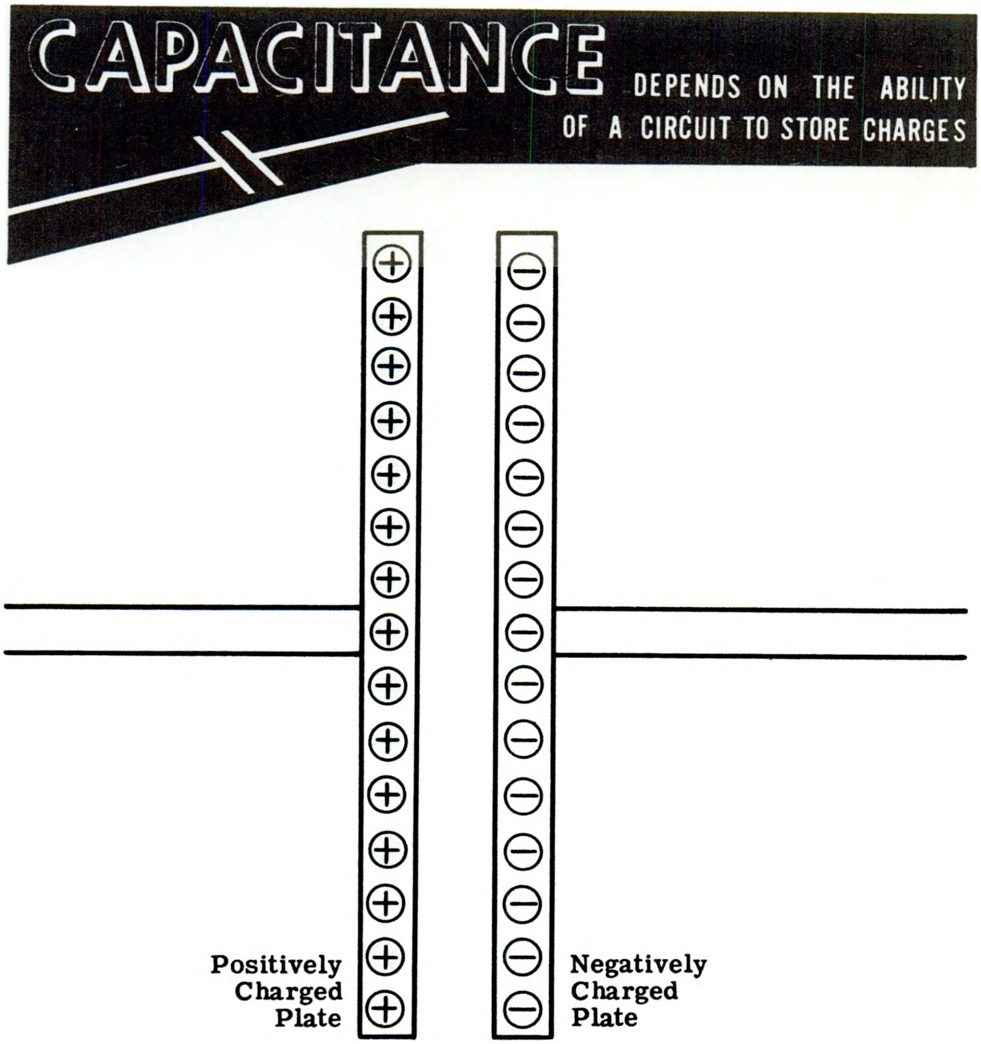
When the voltage across an electric circuit changes, the circuit opposes this change. This opposition is called "capacitance." Like inductance, capacitance cannot be seen, but its effect is present in every electrical circuit whenever the circuit voltage changes.


+
0
VOLTAGE
CAPACITANCE
WHEN THE VOLTAGE INCREASES, CAPACITANCE TRIES TO HOLD IT DOWN!
+
0
VOLTAGE
CAPACITANCE
WHEN THE VOLTAGE DECREASES, CAPACITANCE TRIES TO HOLD IT UP!

Because d-c voltage usually varies only when it is turned on and off, capacitance affects d-c circuits only at these times. In a-c circuits, however, the voltage is continuously changing, so that the effect of capacitance is continuous. The amount of capacitance present in a circuit depends on the physical construction of the circuit and the electrical devices used. The capacitance may be so small that its effect on circuit voltage is negligible.

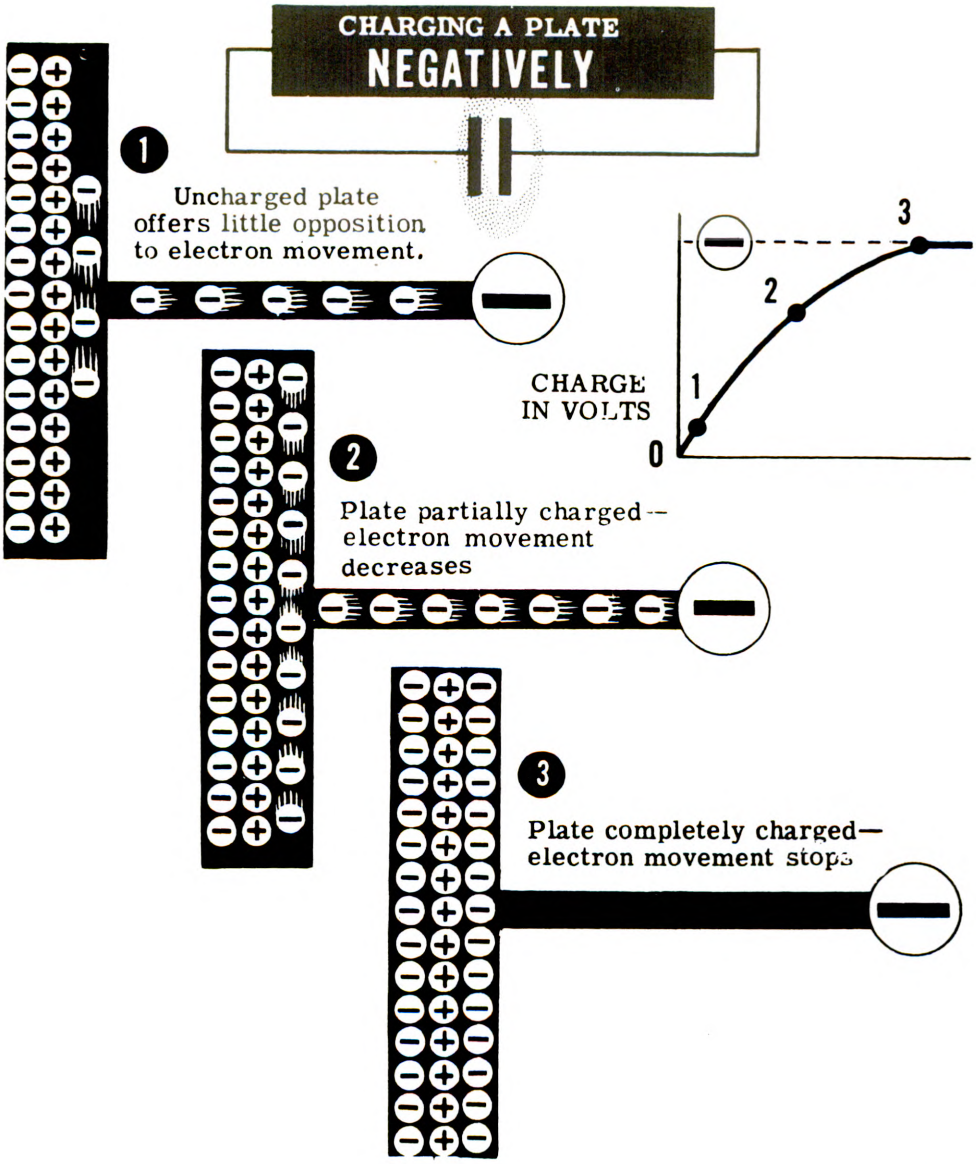
Electrical devices which are used to add capacitance are called "capacitors." Another term frequently used instead of capacitor is "condenser." You will often find the words capacitor and condenser used interchangeably, but they mean the same thing.

Capacitance exists in an electric circuit because certain parts of the circuit are able to store electric charges. Consider two flat metal plates placed parallel to each other, but not touching. You have already found out--while working with static electricity--that these plates can be charged either positively or negatively, depending on the charge which you transfer to them. If charged negatively, a plate will take extra electrons, but if charged positively, it will give up some of its electrons. Thus the plates may have either an excess or lack of electrons.


CAPACITANCE DEPENDS ON THE ABILITY OF A CIRCUIT TO STORE CHARGES
Positively Charged Plate
Negatively Charged Plate

HOW CAPACITORS ARE CHARGED AND DISCHARGED

In order to charge the plates, an electrical force is required. The greater the charge to be placed on each plate, the greater the electrical force required. For example, to charge a plate negatively, you must force extra electrons onto it from a source of negative charge. The first few extra electrons go onto the plate easily but, once there, they oppose or repel any other electrons which try to follow them. As more electrons are forced onto the plate, this repelling force increases, so that a greater force is required to move additional electrons. When the negative repelling force equals the charging force, no more electrons will move onto the plate.


CHARGING A PLATE NEGATIVELY

1 Uncharged plate offers little opposition to electron movement.

2 Plate partially charged— electron movement decreases

3 Plate completely charged— electron movement stops

Similarly, if electrons are removed from a plate by the attraction of a positive charge, the plate is positively charged. The first few electrons leave quite easily; but, as more electrons leave, a strong positive charge is built up on the plate. This positive charge attracts electrons and makes it more difficult to pull them away. When this positive attracting force equals the charging force, no more electrons leave the plate.

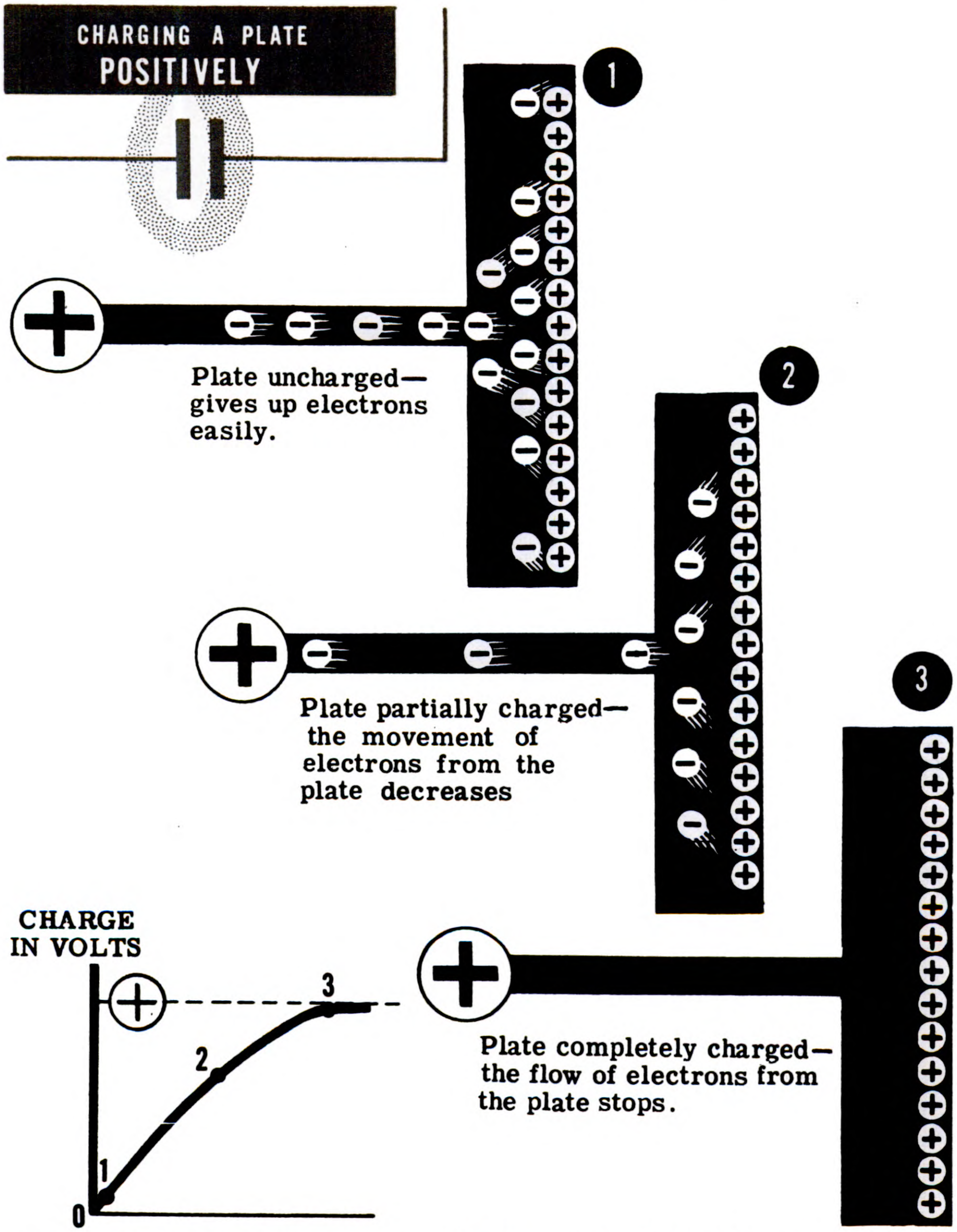


Plate uncharged—gives up electrons easily.

Plate partially charged—the movement of electrons from the plate decreases

Plate completely charged—the flow of electrons from the plate stops.

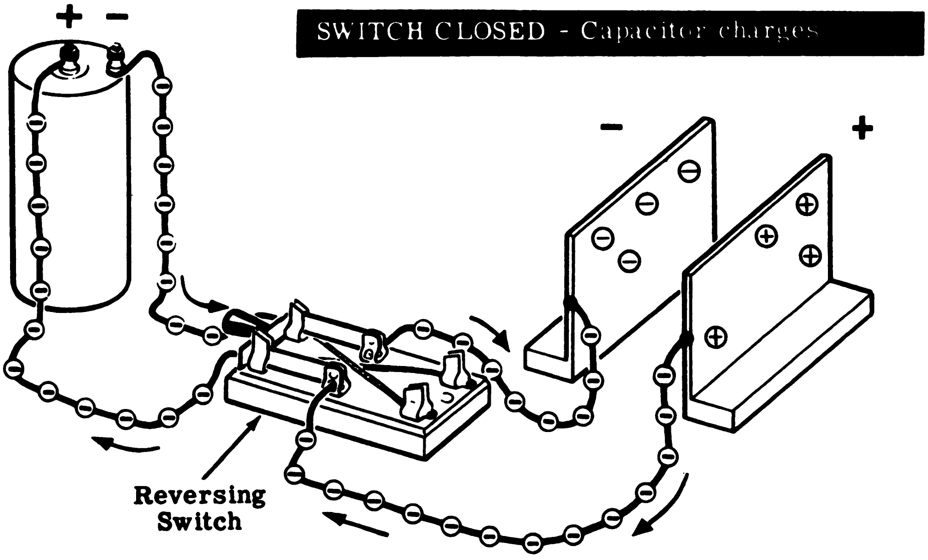
With a d-c voltage source, current will flow in a capacitive circuit only long enough to charge the capacitor (often called a condenser). When the d-c circuit switch is closed, an ammeter connected to read circuit current would show that a very large current flows at first, since the condenser plates are uncharged. Then, as the plates gain polarity and oppose additional charge, the charging current decreases until it reaches zero--at the moment the charge on the plates equals the voltage of the d-c voltage source.

This current which charges a capacitor flows only for the first moment after the switch is closed. After this momentary flow the current stops, since the plates of the capacitor are separated by an insulator which does not allow electrons to pass through it. Thus, capacitors or condensers will not allow d-c current to flow continuously through a circuit.

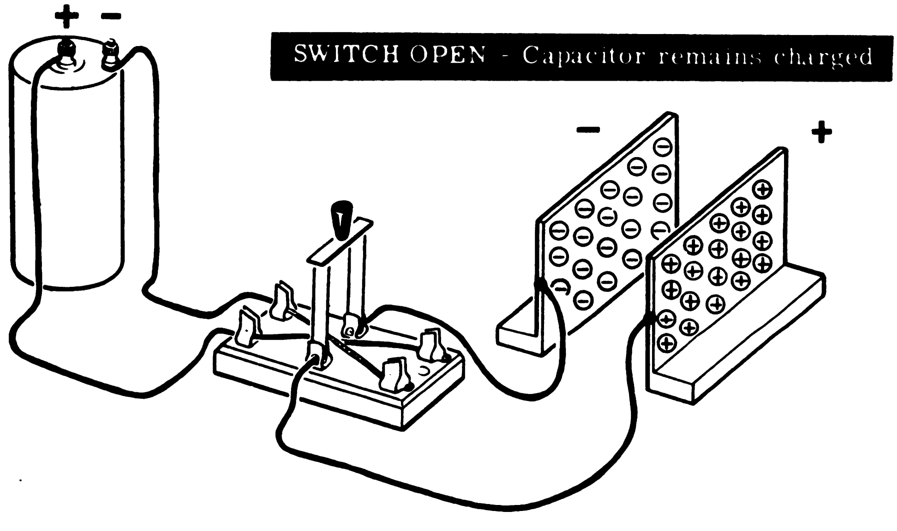
When the switch is opened, the plates remain charged, since there is no path between the two plates through which they can discharge. As long as no discharge path is provided, the voltage between the plates will remain the same. If the switch is again closed, there will be no effect on the circuit, since the capacitor is already charged.

While a capacitor blocks the flow of d-c current it affects an a-c circuit differently, allowing d-c current to flow through the circuit. To see how this works, consider what happens in the d-c circuit if a double-throw switch is used with the dry cell so that the charge to each plate is reversed as the switch is closed--first in one position and then in the other.

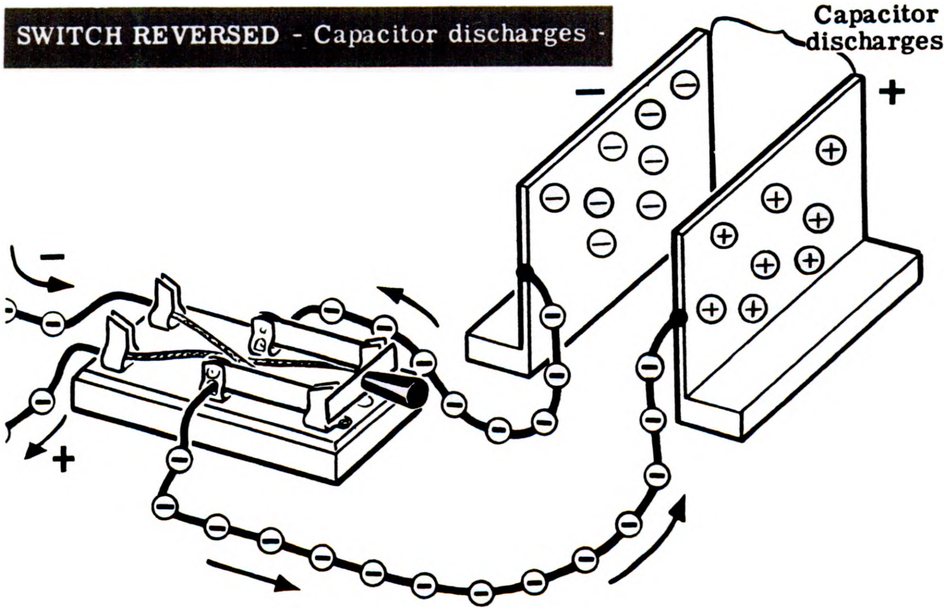
When the switch is first closed, the condenser charges, with each plate being charged in the same polarity as that of the cell terminal to which it is connected.

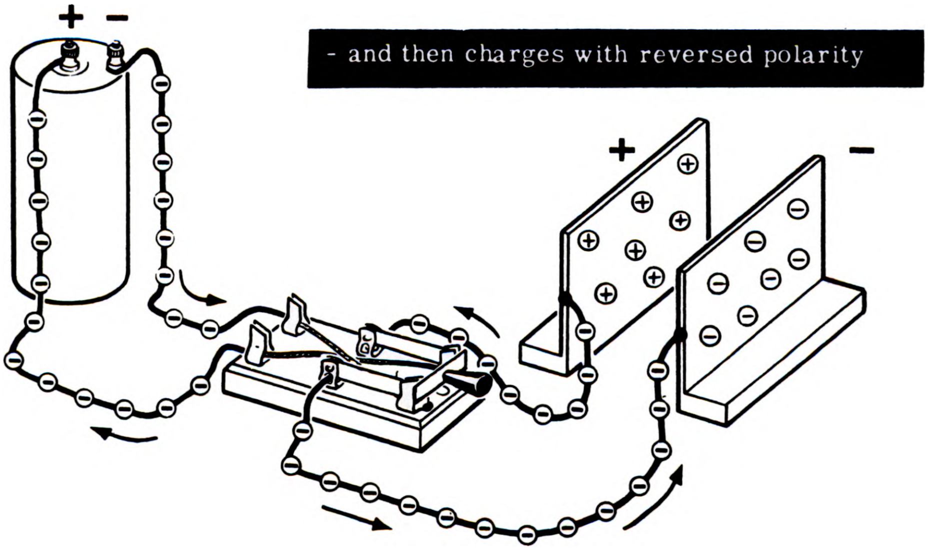


Whenever the switch is opened, the condenser retains the charges on its plates equal to the cell voltage.



If the switch is then closed in its original position, no current flows since the condenser is charged in that polarity. However, if the switch is closed in the opposite direction, the condenser plates are connected to cell terminals opposite in polarity to their charges. The positively charged plate then is connected to the negative cell terminal and will take electrons from the cell--first to neutralize the positive charge, then to become charged negatively until the condenser charge is in the same polarity and of equal voltage to that of the cell. The negatively charged plate gives up electrons to the cell, since it must take on a positive charge equal to that of the cell terminal to which it is connected.


SWITCH REVERSED - Capacitor discharges -


- and then charges with reversed polarity

If a zero-center ammeter which can read current flow in both directions is inserted in series with one of the capacitor plates, it will indicate a current flow each time the plate is charged. When the reversing switch is first closed, it shows a current flow in the direction of the original charge. Then, when the cell polarity is reversed, it shows a current flow in the opposite direction as the plate first discharges, then charges in the opposite polarity. The meter shows that current flows only momentarily, however, each time the cell polarity is reversed.

Suppose you switch the cell polarity fast enough so that at the instant the condenser plates become charged in one polarity, the cell polarity is reversed. The meter needle now moves continuously--first showing a current flow in one direction, then in the opposite direction. While no electrons move through the air from one plate to the other, the meter shows that current is continuously flowing to and from the condenser plates.

If a source of a-c voltage is used instead of the dry cell and reversing switch, the polarity of the voltage source is automatically changed each half cycle. If the frequency of the a-c voltage is low enough, the ammeter will show current flow in both directions, changing each half cycle as the a-c polarity reverses.

The standard commercial frequency is 60 cycles so that a zero-center ammeter will not show the current flow, since the meter pointer cannot move fast enough. Even though it did, you would not be able to see the movement because of its speed. However, an a-c ammeter inserted in place of the zero-center ammeter shows a continuous current flow when the a-c voltage source is used, indicating that in the meter and in the circuit there is a flow of a-c current. Remember that this current flow represents the continuous charging and discharging of the capacitor plates, and that NO ACTUAL ELECTRON MOVEMENT TAKES PLACE DIRECTLY BETWEEN THE PLATES OF THE CAPACITOR. Capacitors are considered to pass a-c current, because current actually flows continuously in all parts of the circuit except the insulating material between the capacitor plates.

UNITS OF CAPACITANCE

The action of capacitance in a circuit is to store a charge and to increase its charge if the voltage rises, or discharge if the voltage falls. Every circuit has some capacitance, with the amount depending on the ability of the circuit to store a charge.

The basic unit of capacitance is the farad, but the storage capacity of a farad is much too great to use as the unit of capacitance for practical electrical circuits. Because of this, the units normally used are the microfarad (equal to one-millionth of a farad). Since electrical formulas use capacitance stated in farads, it is necessary that you are able to change the various units of capacitance to other units. Again, the method of changing units is exactly like that used for changing units of voltage, current, ohms, etc. To change to larger units, the decimal point moves to the left; to change to smaller units, the decimal is moved to the right.

CHANGING UNITS OF CAPACITANCE

MICROFARADS TO FARADS
Move the decimal point 6 places to the left.
120 mfd equals 0.000120 farads

FARADS TO MICROFARADS
Move the decimal point 6 places to the right.
8 farads equals 8,000,000 mfd

MICROMICROFARADS TO FARADS
Move the decimal point 12 places to the left.
1500 mmf equals 0.000000001500 farad

FARADS TO MICROMICROFARADS
Move the decimal point 12 places to the right.
2 farads equals 2,000,000,000,000 mmf

MICROMICROFARADS TO MICROFARADS
Move the decimal point 6 places to the left.
250 mmf equals 0.000250 mfd

MICROFARADS TO MICROMICROFARADS
Move the decimal point 6 places to the right.
2 mfd equals 2,000,000 mmf

In electrical formulas the letter C is used to denote capacitance in farads.

CAPACITOR SYMBOLS

Draw two different schematic symbols to represent fixed condensers.

Draw two different schematic symbols to represent variable capacitors.

CAPACITANCE IN A-C CIRCUITS

JOB SHEET NO. 22

Fill in the blank spaces with the proper words or values.

1. The property of a circuit that opposes any voltage change is called ______________.
2. Electrical devices which are used to add capacitance to a circuit are called ______________ or ______________.
3. In d-c circuits fully charged capacitor plates prevent ______________.
4. Capacitors allow a-c current flow because the capacitor is ______________.
5. The basic unit of capacitance is the ______________.
6. The normal working units of capacitance are ______________ and ______________.
7. One mfd equals ______________ farads.
8. One mmf equals ______________ farads.
9. One farad equals ______________ mfd.
10. One farad equals ______________ mmf.
11. 0.04 mfd equals ______________ farads.
12. 00.4 mfd equals ______________ mmf.
13. 5000 mmf equal ______________ mfd.
14. 0.00001 farads equals ______________ mfd.
15. 20,000 mmf equal ______________ mfd.
16. 20,000 mmf equal ______________ farads.

SECTION IV

TOPIC 5

CAPACITORS AND CAPACITIVE REACTANCE

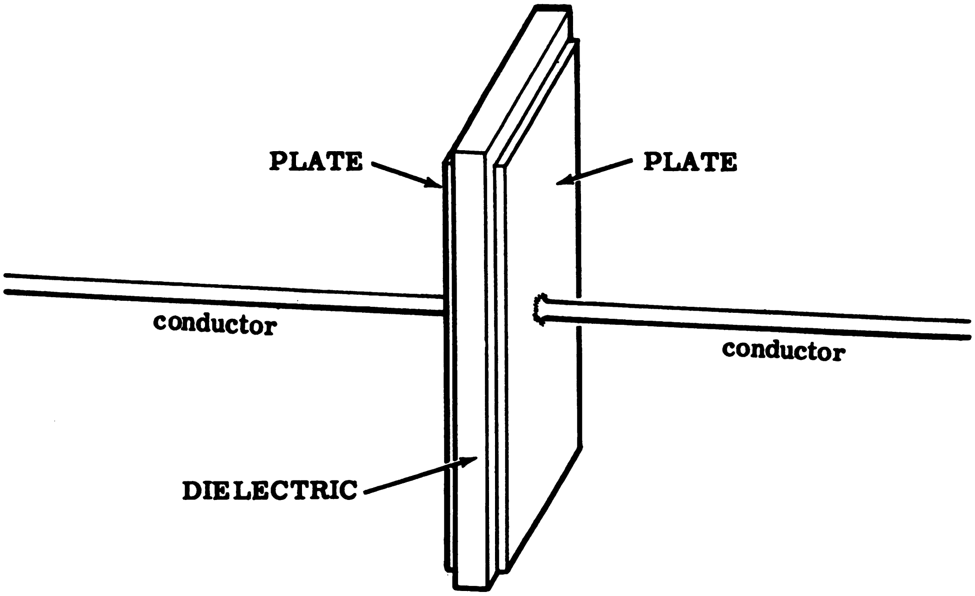
A. You have learned:

1. About Fire Control in general.
2. About electricity fundamentals.
3. About d-c circuits.
4. What a-c is.
5. About resistive a-c circuits.
6. About inductance and power in a-c circuits.
7. About capacitance in a-c circuits.

B. You are learning:	References:
1. About the Construction and Types of Capacitors.	NavPers 10622 B, pages 249 to 254 NavPers 10170, pages 172 to 173
2. About the Factors that affect Capacitance.	NavPers 10622 B, pages 249 to 254 NavPers 10170, pages 174 to 175
3. About the Ratings of Capacitors.	NavPers 10170, pages 173 to 176
4. About Capacitive Reactance and its effect.	NavPers 10622 B, pages 249 to 255 NavPers 10170, pages 177 to 178
5. About Power in Capacitive Circuits.	NavPers 10170, pages 186 to 187

C. You will acquire skill in:

1. Identifying the ratings of capacitors found in Mk 4 Power Drive.
2. Computing capacitive reactance in a circuit.
3. Computing the properties of power in a circuit.



CAPACITOR CONSTRUCTION

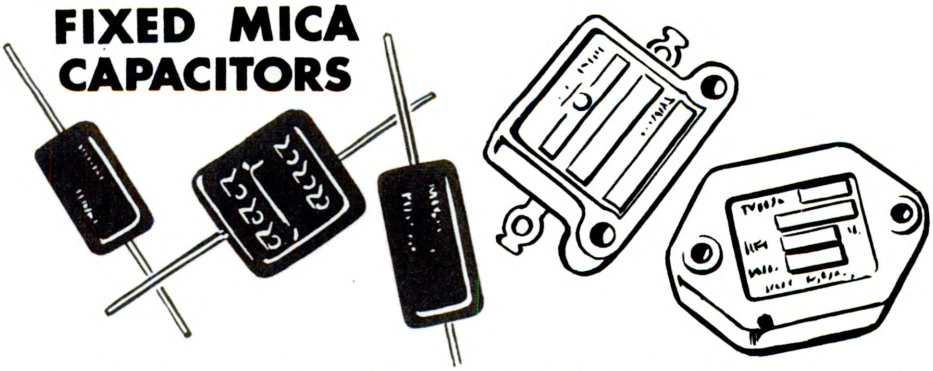
CONSTRUCTION AND TYPES OF CAPACITORS

Basically, capacitors consist of two plates which can be charged--separated by an insulating material called the "dielectric." While early condensers were made with solid metal plates, newer types of condensers use metal foil, particularly aluminum foil, for the plates. Dielectric materials commonly used include air, paper, wax, oil, glass, or mica.

Many kinds of capacitors are used in electricity and electronics. In order to choose the best type for a particular job, you should know how they are made and operate. You also should be familiar with the symbols used to indicate certain special types of capacitors. Condensers (capacitors) are generally classified according to their dielectric material.

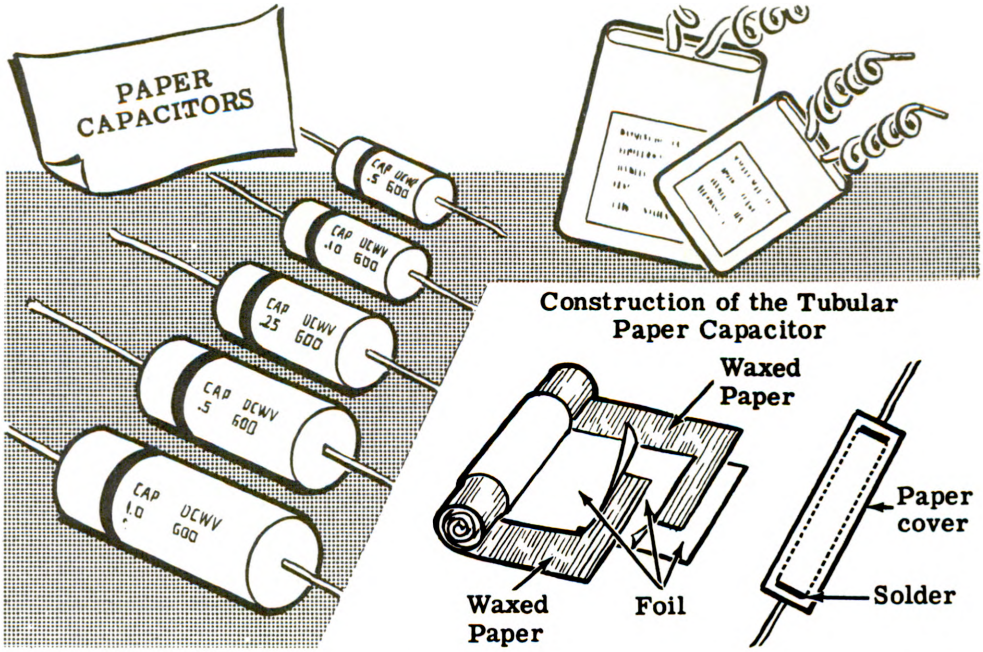
The most basic type of capacitor (which may be either fixed or variable) is the air condenser, constructed of metal plates with air spaces between them. A similar type of condenser is the vacuum condenser, which consists of two plates separated by a vacuum--the vacuum being the dielectric. Because the plates must be rather widely spaced to prevent arcing, the capacitance of air and vacuum condensers is low, usually between 1 mmf and 500 mmf.

A special type of mica condenser, which is variable and usually has a maximum value of less than 500 mmf, consists of two plates with a sheet of mica between them. A screw adjustment is used to force the plates together, and adjustment of this screw varies the capacitance of the condenser. Several layers of plates and mica are used in larger condensers of this type. This kind of condenser is sometimes built onto a large variable air condenser, to be used in parallel with the larger variable condenser and to provide a finer adjustment of capacitance.

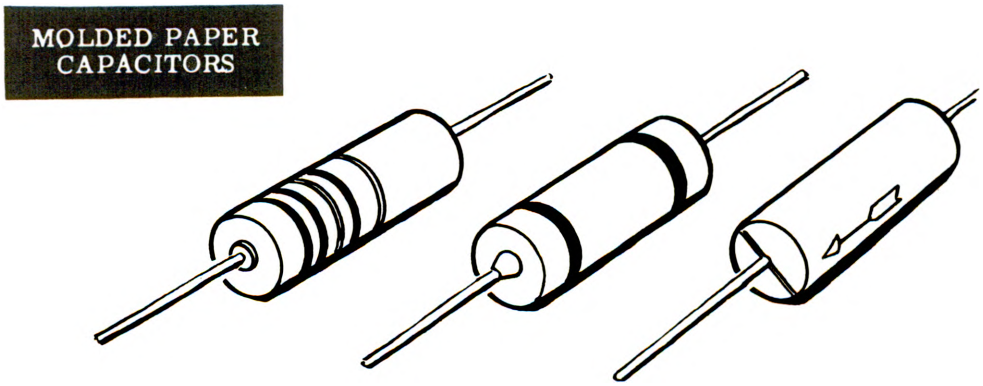


Fixed mica capacitors consist of thin metal foil plates separated by sheet mica and molded into a plastic cover. These capacitors are made in a capacity range between 10 mmf and 0.01 mfd. Various types of terminals are used to connect mica capacitors into circuits, and these terminals are molded into the plastic with the capacitor plates and dielectric. By molding the capacitor parts into a plastic case, corrosion and damage to the plates and dielectric are prevented, in addition to making the capacitor mechanically strong. This is one of the types of capacitors found in the converter amplifier of the Mk 4 Power Drive.

Paper capacitors use strips of metal foil as plates, separated by strips of waxed paper. Paper capacitors range in value from 250 mmf to 1 mfd for most uses, although larger paper capacitors are made for special applications. Since very long strips of paper are required to obtain a usable capacitance, the strips of foil and waxed paper are rolled together to form a cartridge. This cartridge, including leads attached to the plates, is sealed in wax to prevent moisture leakage and corrosion of the plates. Many different kinds of outer covering are used for paper capacitors, the simplest being a tubular cardboard.

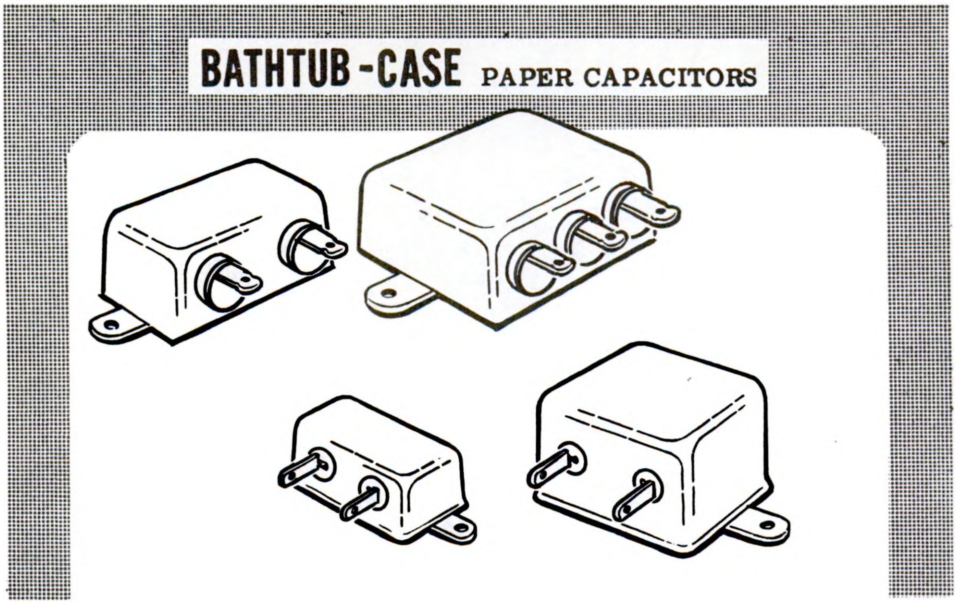


Some types of paper capacitors are encased in a mold of very hard plastic. Capacitors which are so constructed are very rugged and may be used over a much wider temperature range than the cardboard case type, since the wax used in the tubular cardboard type melts at high temperatures and escapes through the open ends of the cardboard case.

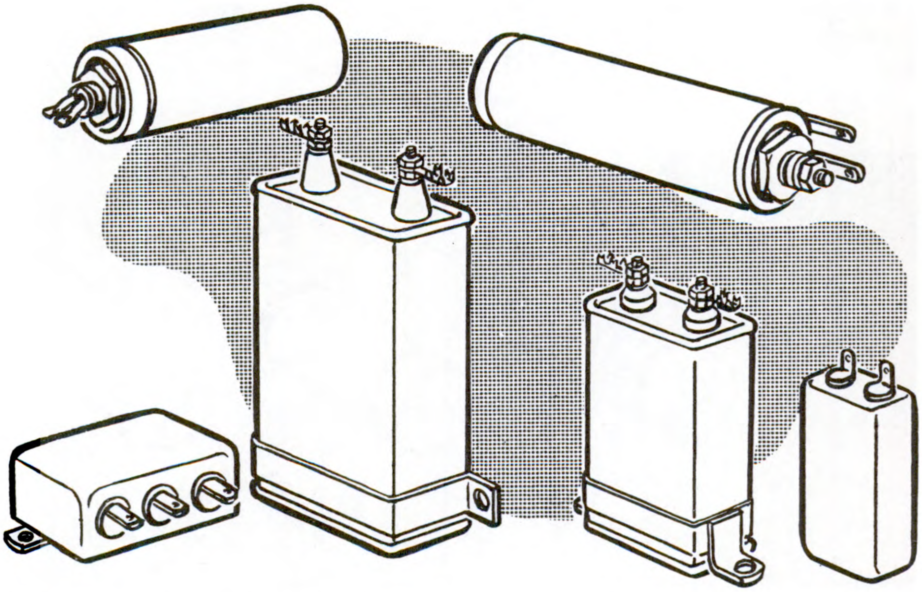


Bathtub-style capacitors are paper capacitor cartridges hermetically sealed in a metal container. The metal container is sometimes used as one terminal but, if not, it acts as a shield against electrical interference. Also, quite often a single terminal is the common terminal used for serveral different capacitors sealed in one bathtub case. This is another type condenser found in the converter amplifier.

Paper capacitors used for high-voltage circuits (600 volts and higher) are impregnated with oil and are oil filled. The metal container is hermetically sealed, and various types of terminal connections are used. This type is also found in the converter amplifier.



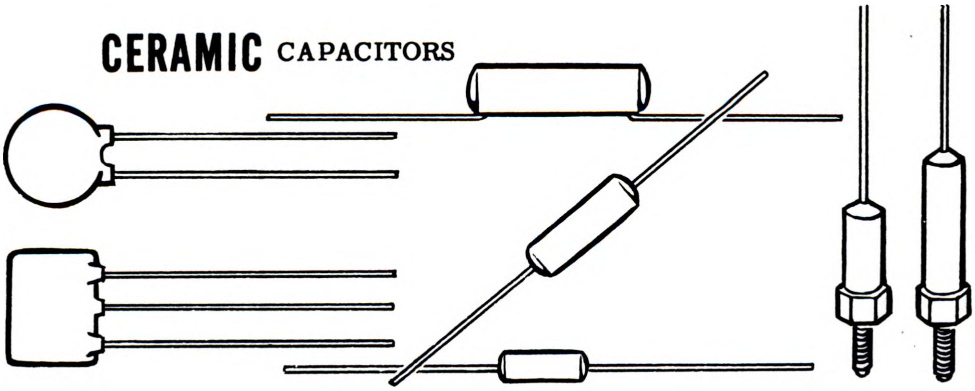
BATHTUB-CASE PAPER CAPACITORS



OIL-FILLED HIGH VOLTAGE PAPER CAPACITORS

A recently developed type of extremely small capacitors, both fixed and variable, use ceramic as the dielectric and a film deposit of silver for the plates. Ceramic capacitors usually range in value between 1 mmf and 0.01 mfd. They are constructed in various shapes, the most common being disk and tubular. Variable ceramic capacitors have one fixed plate of silver film and a movable metal plate which is silver plated. Although ceramic capacitors have a dielectric which will insulate against voltages above 2,000 volts, they are quite small and take up little space, so that they are used in many special circuits for voltages of 10,000 volts or more.

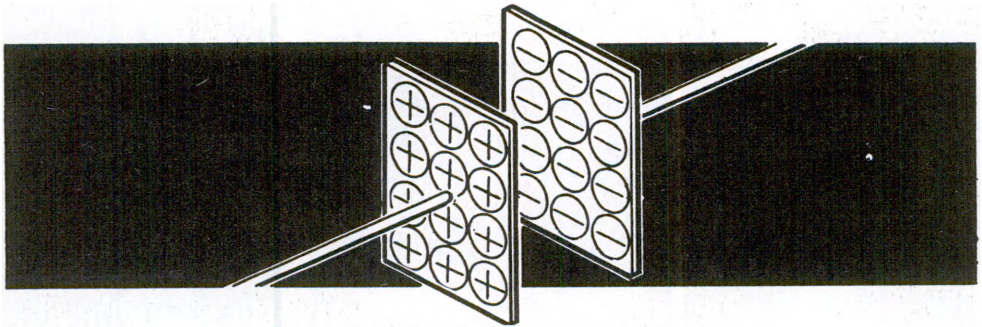
For values of capacitance greater than 1 mfd, the physical size of a paper or a mica capacitor becomes excessive. Electrolytic capacitors are used for such values of capacitance, ranging from 1 to 1,000 mfd. Unlike other types of capacitors, the electrolytic



CERAMIC CAPACITORS

capacitor is polarized and, if connected in the wrong polarity, will break down and act as a short circuit. A special type of electrolytic capacitor is made which compensates for changing polarity, and may be used on a-c.

Electrolytic capacitors are constructed in a wide variety of shapes and physical sizes, using either cardboard or metal cases and various types of terminal connections. Remember that unless an electrolytic is designed for use on a-c, such as a motor-starting capacitor, you must always be careful to connect it only in a d-c circuit and to observe the correct polarity.



Larger plates hold more electrons

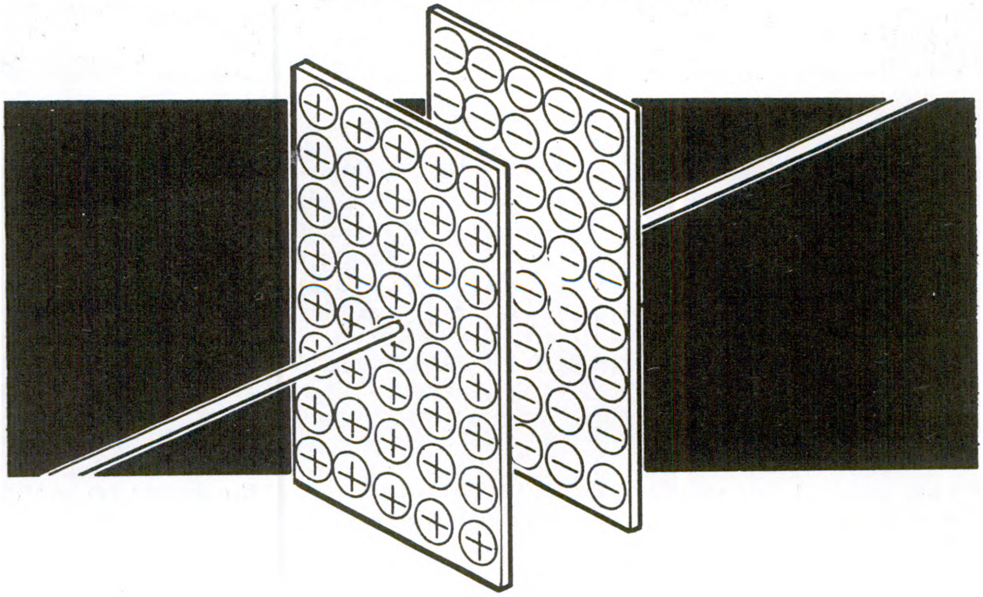
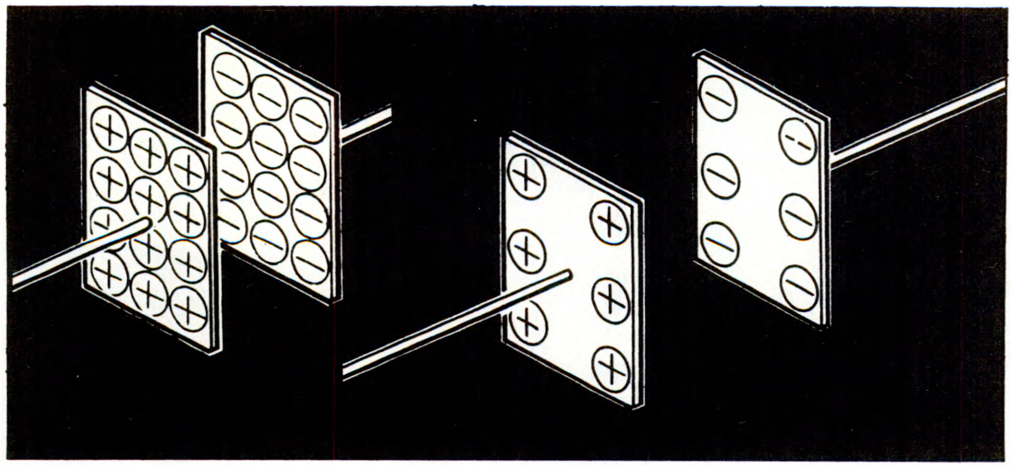


PLATE AREA

Plate area is a very important factor in determining the amount of capacitance, since the CAPACITANCE VARIES DIRECTLY WITH THE AREA OF THE PLATES. A large plate area has room for more excess electrons than a small area and, thus, can hold a greater charge. Similarly, the large plate area has more electrons to give up and will hold a much larger positive charge than will a small plate area. Thus, an increase in plate area increases capacitance, and a decrease in plate area decreases capacitance.

The effect that two charged bodies have on each other depends on the distance between the two. Since the action of capacitance depends on the two plates and the difference is their charges, the amount of capacitance changes when the distance between the plates changes. THE CAPACITANCE BETWEEN TWO PLATES INCREASES AS THE PLATES ARE BROUGHT CLOSER TOGETHER and decreases as the plates are moved apart. This occurs because the closer the plates are to each other, the greater the effect a charge on one plate will have on the charge of the other plate.

When an excess of electrons appears on one plate of a condenser, electrons are forced off the opposite plate, inducing a positive charge on this plate. Similarly, a positively charged plate induces a negative charge on the opposite plate. The closer the plates are to each other, the stronger the force between them, and this force increases the capacitance of a circuit.

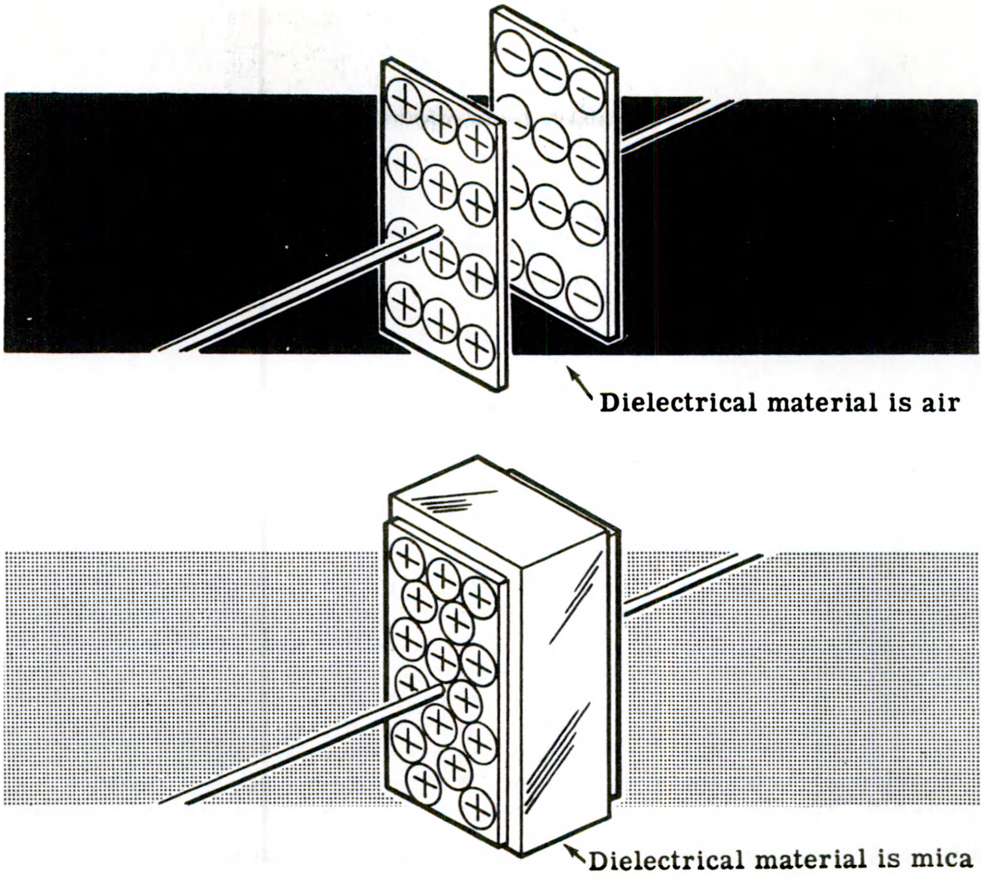


DISTANCE BETWEEN THE PLATES

Using the same plates fixed a certain distance apart, the capacitance will change if different insulating materials are used for the dielectric. The effect of different materials is compared to that of air--that is, if the condenser has a given capacitance when air is used as the dielectric, other materials used instead of air will multiply the capacitance by a certain amount called the "dielectric constant." For example, some types of oiled paper have a dielectric constant of 3 and if this waxed paper is placed between the plates, the capacitance will be 3 times greater than when air is used as the dielectric. DIFFERENT MATERIALS HAVE DIFFERENT DIELECTRIC CONSTANTS, AND THUS WILL CHANGE THE CAPACITANCE WHEN THEY ARE PLACED BETWEEN THE PLATES TO ACT AS THE DIELECTRIC.

When you connect capacitors in series or in parallel, the effect on the total capacitance is opposite to that for similarly connected resistors.

Connecting resistors in series increases the total resistance because it lengthens the resistance path through which current flows, while connecting capacitances in

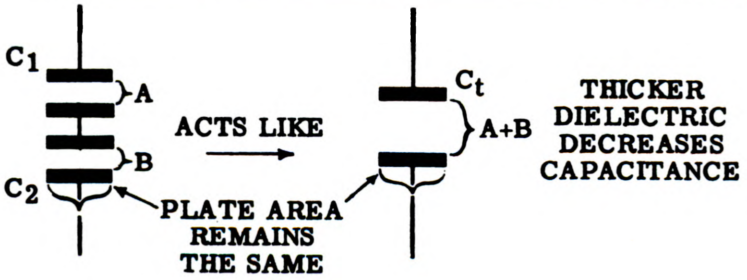


Dielectrical material is air

Dielectrical material is mica

DIELECTRIC MATERIAL

Series Connection INCREASES THE THICKNESS OF THE DIELECTRIC

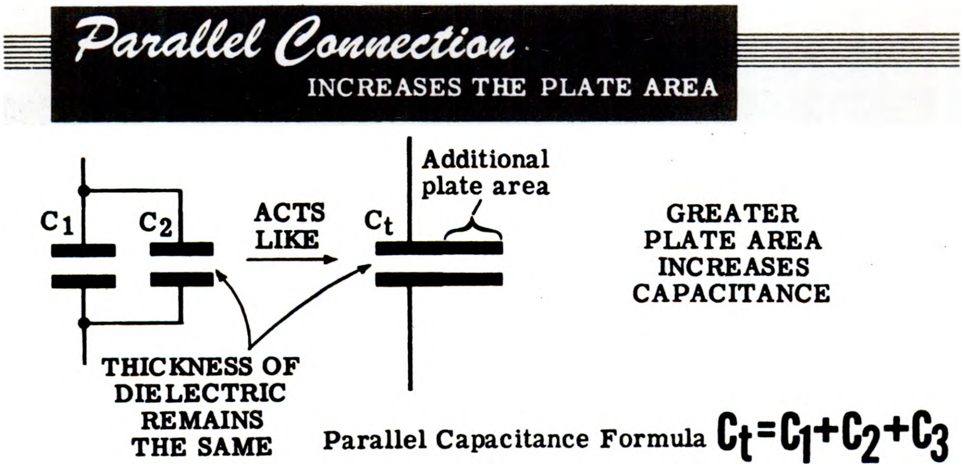

C1
A
B
C2
ACTS LIKE
Ct
A+B
PLATE AREA REMAINS THE SAME
THICKER DIELECTRIC DECREASES CAPACITANCE

Series Capacitance Formula

$$C_t = \frac{C_1 \times C_2}{C_1 + C_2}$$

series decreases the total capacitance since it effectively increases the spacing between the plates. To find the total capacitance of series-connected capacitors, a formula is used similar to the formula for parallel resistances.

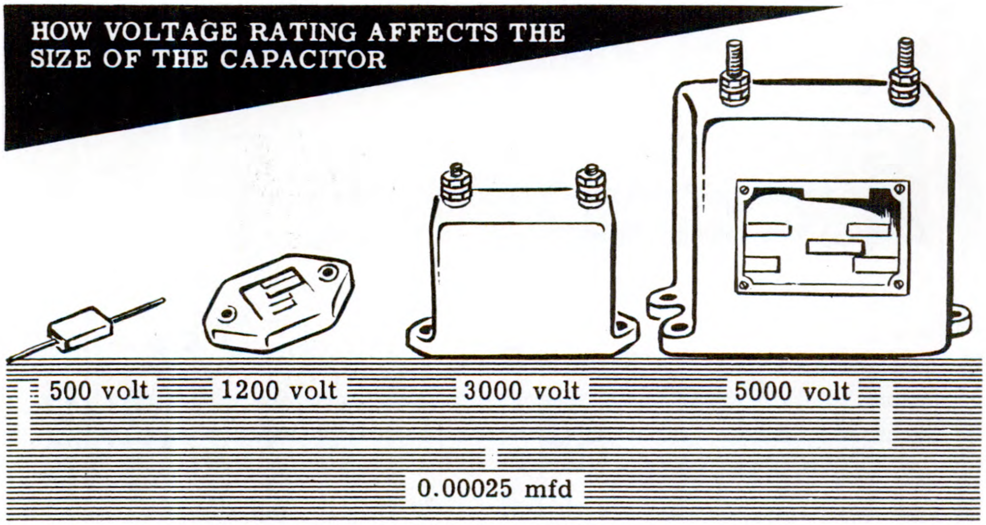
When resistors are connected in parallel, the total resistance decreases since the cross section through which current can flow increases. The reverse is true of parallel-connected capacitors. The total capacitance increases since the plate area receiving a charge increases. The total capacitance for parallel-connected capacitors is found by adding the values of the various capacitors connected in parallel.



Parallel Capacitance Formula $C_t = C_1 + C_2 + C_3$

RATINGS OF CAPACITORS

The voltage applied across the plates of a capacitor is determined by the thickness of the dielectric material which acts as an insulator between the two plates. Capacitors of exactly the same capacitance may have different voltage rating due to a difference in the thickness of the dielectric. If the dielectric thickness is increased, the plates will be further apart, reducing the capacitance so that the plate areas must be increased to make up for this loss. Thus, capacitors of higher voltage ratings are larger in physical size, since the plates are both larger and further apart. This is true of all types of capacitors regardless of the dielectric used. Shown below are typical mica capacitors having various voltage ratings but the same amount of capacitance.


HOW VOLTAGE RATING AFFECTS THE SIZE OF THE CAPACITOR
500 volt
1200 volt
3000 volt
5000 volt
0.00025 mfd

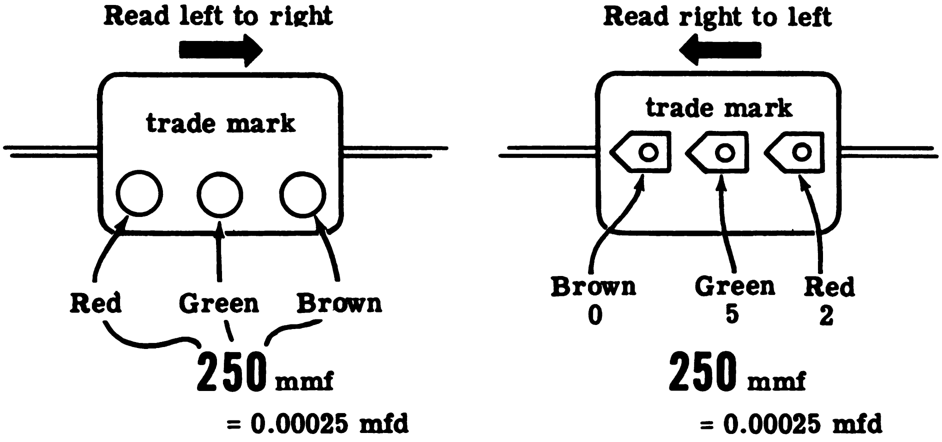
The capacitance value and voltage rating of most capacitors is printed or stamped on the body of the capacitors, together with the polarity in the case of electrolytics. Voltage ratings marked on the body of a capacitor usually refer to the maximum d-c voltage which can be applied across the terminals without a breakdown of the dielectric insulation. Many capacitors are marked with a color code similar to the resistor color code, and the corresponding colors and numbers are the same for the two codes. Suppose you review the colors and numbers which are used.

The order in which these colors are used by the different manufacturers varies. The simplest color-code marking uses three dots of color, which give the value of

Color	No.	Tolerance	Voltage Rating	Color	No.	Tolerance	Voltage Rating
Black	0		-	Violet	7	7%	700
Brown	1	1%	100	Gray	8	8%	800
Red	2	2%	200	White	9	9%	900
Orange	3	3%	300	Gold	-	5%	1,000
Yellow	4	4%	400	Silver	-	10%	2,000
Green	5	5%	500	No Color	-	20%	-
Blue	6	6%	600				

CAPACITOR COLOR CODE

capacitance in mmf. The first two dots represent the first two numbers and the last dot the number of zeros to be added. All color-coded values are in mmf, and must be changed to mfd if the answer in mfd is desired. If no arrows are present, the capacitor is placed in such a position that the trademark can be read correctly, and the three dots of color are read from LEFT to RIGHT. When each dot is placed on a small arrow, they are read in the direction of the arrows. If the dots are red, green, and brown, reading in the proper direction, the capacitance is 250 mmf or 0.00025 mfd as shown below. If no tolerance and voltage ratings are indicated, they are assumed to be ± 20% at 500 volts.

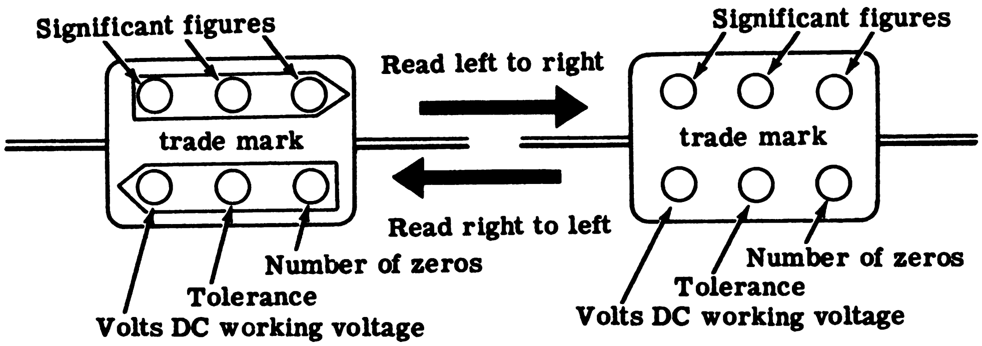


HOW TO USE THE CAPACITOR COLOR CODE FOR CAPACITORS MARKED WITH THREE COLORS

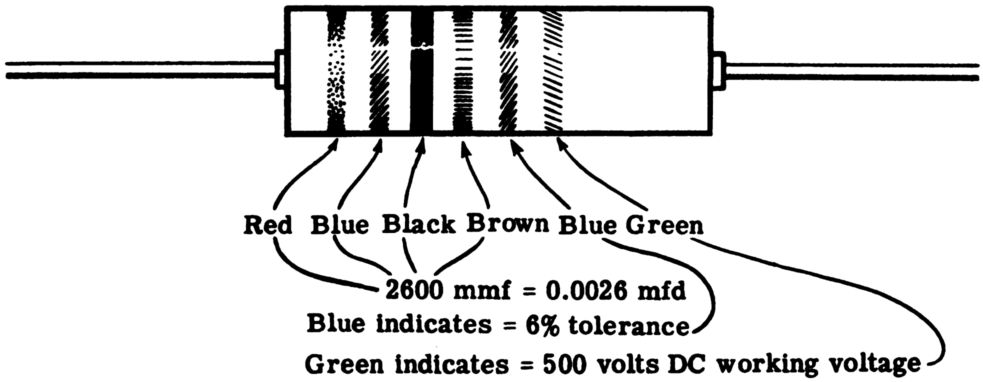
Capacitors which are marked with six dots of color are coded for percentage of accuracy (tolerance) and voltage rating, in addition to the capacitance value. The top row of dots is read from LEFT to RIGHT, and the bottom row is read from RIGHT to LEFT. In this type of marking, 3 digits are obtained from the top row of dots; from the bottom row, from RIGHT to LEFT in order, are read the number of zeros, the percentage tolerance, and the voltage rating.

Suppose the six dots read in the correct order are brown, orange, green, red, silver, and blue. The capacitor, then, has a capacitance of 13,500 mmf, a tolerance of 10 percent, and a voltage rating of 600 volts.

COLOR-CODE MARKING IS USED NOT ONLY ON MICA OR CERAMIC CAPACITORS, BUT ALSO IS USED WITH MOLDED TUBULAR PAPER CAPACITORS. THE MARKING, THEN, IS DONE WITH BANDS OF COLOR WHICH ARE READ FROM THE BAND NEAREST ONE END OF THE CAPACITOR, IN ORDER, TOWARD THE CENTER, THE COLORS ARE READ IN THE SAME MANNER AS THE SIX-DOT SYSTEM, WITH



HOW TO USE THE CAPACITOR COLOR CODE FOR CAPACITORS MARKED WITH THREE COLORS


Red Blue Black Brown Blue Green
2600 mmf = 0.0026 mfd
Blue indicates = 6% tolerance
Green indicates = 500 volts DC working voltage

BAND MARKING OF MOLDED PAPER CAPACITORS

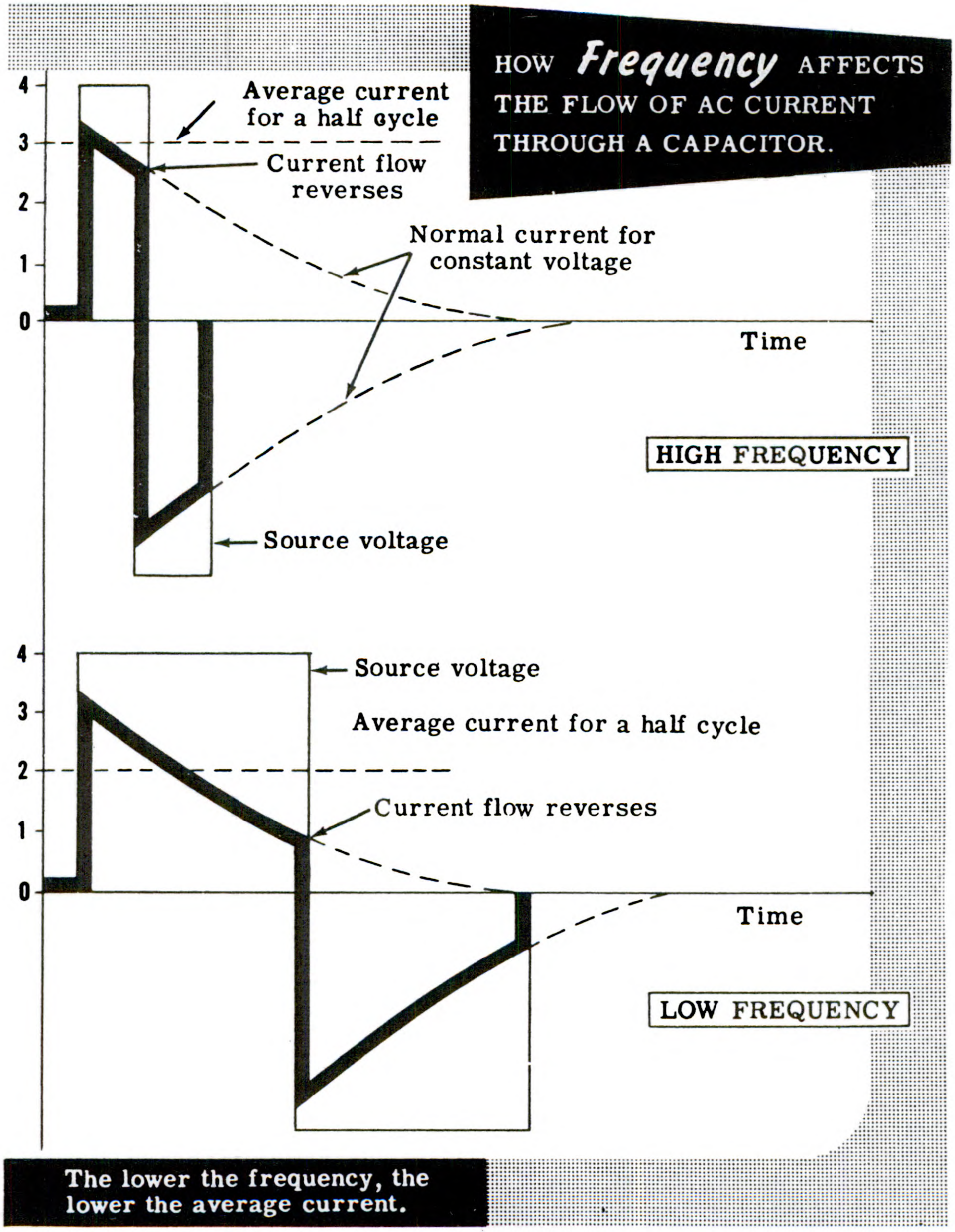
THE FIRST 3 BANDS DENOTING DIGITS, THE FOURTH BAND GIVING THE NUMBER OF ZEROS, THE FIFTH BAND THE TOLERANCE, AND THE SIXTH BAND THE VOLTAGE RATING.

CAPACITIVE REACTANCE AND ITS EFFECT

Capacitive reactance is the opposition to current flow offered by the capacitance of a circuit. When a d-c source is used, current flows only to charge or discharge the capacitor. Since there is no continuous flow of d-c current in a capacitive circuit, the capacitive reactance to d-c is considered infinite. A-c continuously varies in value and polarity; therefore, the capacitor is continuously charging and discharging, resulting in a continuous circuit current flow and a finite value of capacitive reactance.

The charge and discharge currents of a capacitor start at a maximum value and fall to zero as the capacitor becomes either fully charged or discharged. In the case of a charging capacitor, the uncharged plates offer little opposition to the charging current at first, but as they become charged, they offer more and more opposition, reducing the current flow. Similarly, the discharge current is high at the beginning of the discharge since the voltage of the charged capacitor is high; but, as the capacitor discharges, its charge voltage drops, resulting in less current flow. Since the charging and discharging currents are highest at the beginning of the charge and discharge of a capacitor, the average current is higher if the polarity is reversed rapidly, keeping the current flowing at high values.

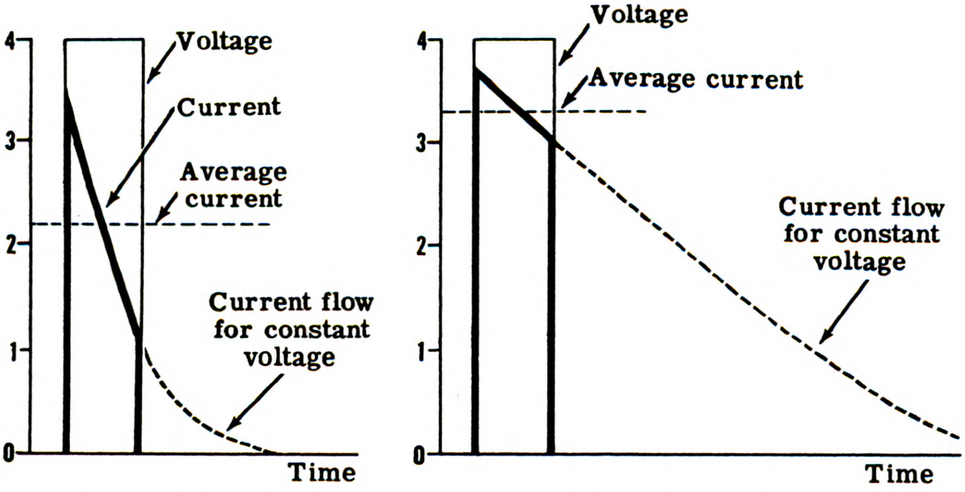
For a given value of capacitance, the amount of current flow in an a-c circuit depends on the frequency of the a-c voltage. The higher the frequency, the greater the current flow, since the charging current in each direction will be reversed before it has time to drop to a low value. If the source voltage is low in frequency, the current will drop to a low value before the polarity reverse, resulting in a lower average value of current flow.



The lower the frequency, the lower the average current.

Comparing the charge current curves for different values of capacitance, you see that the larger the capacitance the longer the current remains at a high value. Thus, if the frequency is the same, a GREATER AVERAGE CURRENT WILL FLOW THROUGH A LARGE CAPACITANCE THAN THROUGH A SMALL CAPACITANCE. This holds true only if the circuit resistances are equal.

The current flow in a capacitive circuit, assuming that there is no change in the resistance, increases with an increase in either frequency or capacitance. Then capacitive reactance--the opposition to current flow through a capacitance--must decrease when the frequency or capacitance increases.



SMALL CAPACITANCE

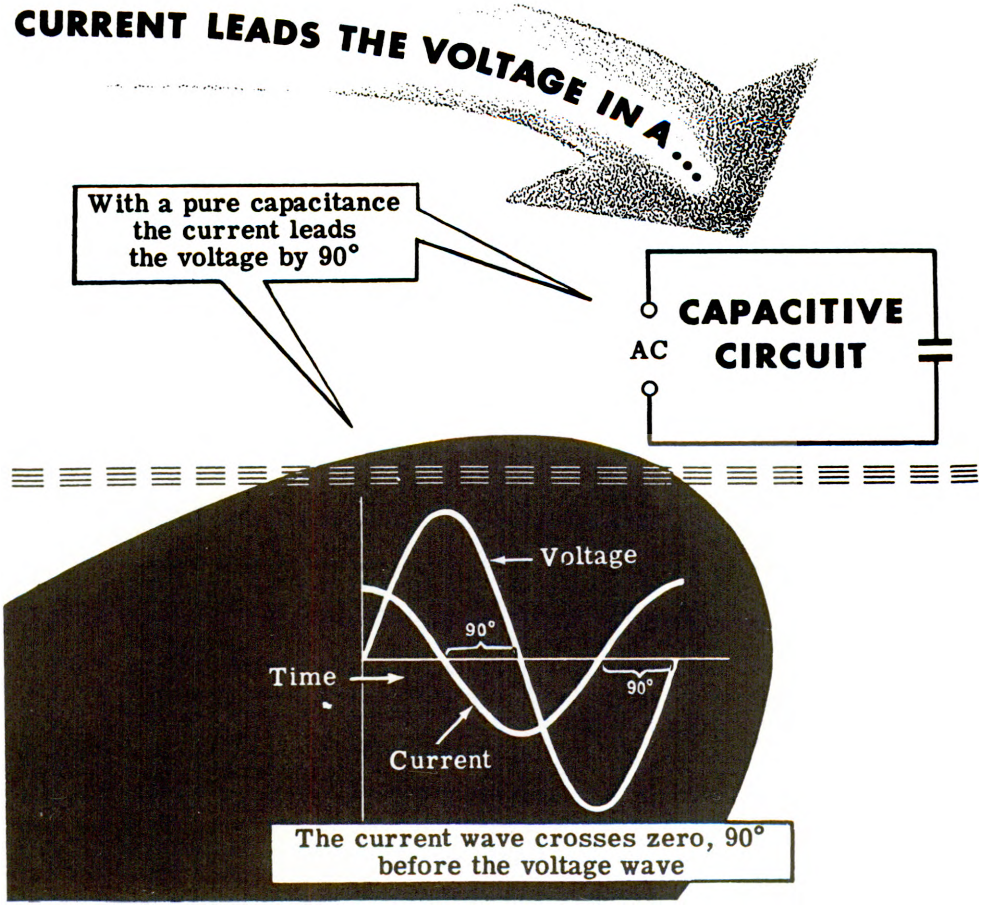
Low
average current
high reactance

LARGE CAPACITANCE

High average current
low reactance

The smaller the capacitance—
the lower the average current.

HOW CAPACITANCE VALVES AFFECT CAPACITIVE REACTANCE



With a pure capacitance
the current leads
the voltage by 90°

The current wave crosses zero, 90°
before the voltage wave

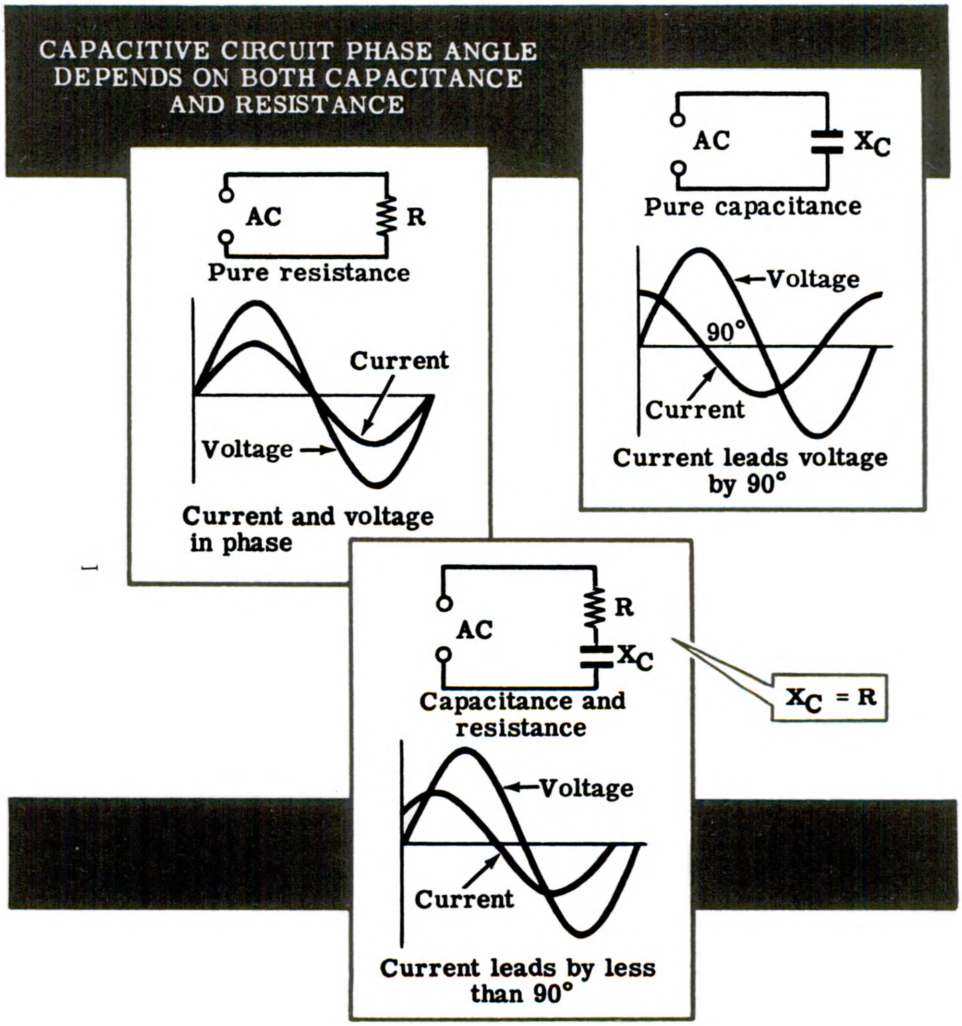
The formula used to obtain capacitive reactance is

$$X_c = \frac{1}{2\pi\ fc}$$

In this formula, X_c is capacitive reactance, f is frequency in cycles, C is capacitance in farads and 2π is a constant number (6.28). Since X_c represents opposition or resistance to current flow, it is expressed in ohms.

The phase relationship between current and voltage waves in a capacitive circuit is exactly the opposite to that of an inductive circuit. In a purely inductive circuit the current wave lags the voltage by 90 degrees, while in a purely capacitive circuit the current wave leads the voltage by 90 degrees.

In a theoretical circuit of pure capacitance and no resistance, the voltage across the capacitance exists only after current flows to charge the plates. At the moment a capacitance starts to charge, the voltage across its plates in zero and the current flow is maximum. As the capacitance charges, the current flow drops towards zero while the voltage rises to its maximum value. When the capacitance reaches full charge, the current is zero and the voltage is maximum. In discharging, the current starts at zero and rises to a maximum in the opposite direction, while the voltage falls from maximum to zero. In comparing the voltage and current waves, you see that the current wave leads the voltage by 90 degrees or, in opposite terms, the voltage wave lags the current by 90 degrees.



CAPACITIVE CIRCUIT PHASE ANGLE DEPENDS ON BOTH CAPACITANCE AND RESISTANCE

AC
R
Pure resistance
Current
Voltage
Current and voltage in phase
AC
X_C
Pure capacitance
Voltage
90°
Current
Current leads voltage by 90°
AC
R
X_C
Capacitance and resistance
X_C = R
Voltage
Current
Current leads by less than 90°

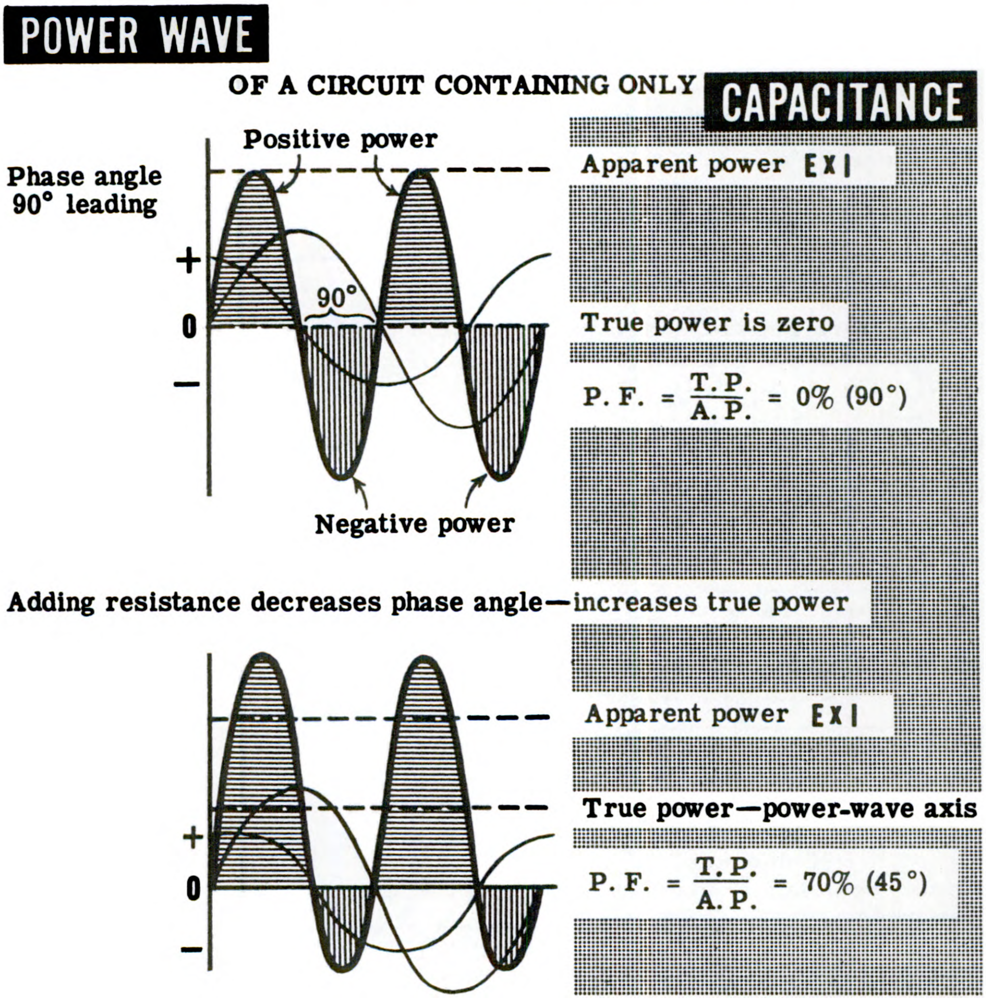
Resistance affects capacitive circuits similarly to the way it affects inductive circuits. Remember, in an inductive circuit containing both inductance and resistance, the current wave lags the voltage wave by an angle between zero degrees and 90 degrees, depending on the ratio of inductive reactance to the resistance. For a purely capacitive circuit, current leads the voltage by 90 degrees; but with both resistance and capacitance in a circuit, the amount of lead--"phase angle"--depends on the ratio between the capacitive reactance and the resistance.

If the capacitive reactance and resistance are equal, they will have an equal effect on the angle of lead resulting in a phase angle of 45 degrees leading. As shown below, the current wave then leads the voltage wave by 45 degrees.

POWER IN CAPACITIVE CIRCUITS

In a capacitive circuit, as in an inductive circuit, the true power used is less than the apparent power of the circuit. Current leads the voltage in a capacitive circuit. The power waveform again is obtained by multiplying the corresponding values of voltage and current to obtain the instantaneous values of power. The power wave of an a-c circuit consisting of pure capacitance is shown below and, like the power wave of a purely inductive circuit, its axis is the same as that of the voltage and current, while its frequency is twice that of the voltage and current. For this circuit, the phase angle between the current wave and voltage wave is 90 degrees, and the negative power equals the positive power.

When resistance is added to a capacitive circuit, the phase angle decreases and the positive power becomes greater than the negative power. The difference between the positive and negative power is the actual power used to heat the resistance, and its amount depends on the ratio of circuit resistance to capacitance.


POWER WAVE
OF A CIRCUIT CONTAINING ONLY CAPACITANCE
Positive power
Phase angle 90° leading
Apparent power E X I
+
0
–
90°
True power is zero
P. F. = $\frac{T.P.}{A.P.}$ = 0% (90°)
Negative power
Adding resistance decreases phase angle—increases true power
Apparent power E X I
True power—power-wave axis
+
0
–
P. F. = $\frac{T.P.}{A.P.}$ = 70% (45°)

JOB SHEET NO 23

1. Capacitors consist of ______________________ and the ______________________.
2. Name three types of capacitors found in the converter amplifier of the Mk 4 Power Drive.

   a. ____________________________________
   b. ____________________________________
   c. ____________________________________

3. List the three factors that affect capacitance.

   a. ____
   b. ____
   c. ____

4. When capacitors are connected in series, the total capacitance will ________________ ____.
5. What formula is used to find the total capacitance of two capacitors (C1 and C2) connected in series 9?
6. When capacitors are connected in parallel, the total capacitance will ________________ ____.
7. What formula is used to find the total capacitance of capacitors (1, C2, etc.) connected in parallel?
8. The opposition to current flow offered by the capacitance of a circuit is called ______________________.
9. Condensers are rated in ______________________ and ______________________.
10. The unit of measure of capacitive reactance is the ______________________.
11. Capacitive reactance is represented by the symbol ______________________.
12. When the capacitance of a circuit is decreased, the capacitive reactance will ________________________.
13. When the frequency is decreased, the capacitive reactance will ________________ ___________.
14. The formula used to obtain capacitive reactance is: ______________________.
15. In a purely capacitive circuit, the ________________ leads the ________________ ___________ by 90 degrees.
16. With both resistance and capacitance in a circuit, the phase angle depends on the ratio between ____ ____.
17. In a purely capacitive circuit, true power is ______________________________.
18. What is the capacitive reactance of a 10-mfd condenser, if the frequency is 120 cycles per second? Solve to the nearest ohm.

19. What is the capacitive reactance of a 10-mfd condenser, if the frequency is 120 cycles per second? Solve to the nearest ohm.

20. What is the capacitive reactance of a 1-mfd condenser, if the frequency is 60 cycles per second? Solve to the nearest ohm.

SECTION IV

TOPIC 6

IMPEDANCE IN ALTERNATING CURRENT CIRCUITS

A. You have learned:

References:

1. About Fire Control in general.
2. About electricity fundamentals.
3. About d-c circuits.
4. What a-c is.
5. About resistive a-c circuits.
6. About inductance and power in a-c circuits.
7. About capacitance in a-c circuits.
8. About capacitors and capacitive reactance.

B. You are learning:

1. What impedance is.

   NavPers 10170, pages 189 and 190
2. What a vector is and how it is used.
3. How to determine impedance and phase angle in a resistive and inductive circuit.
4. How to determine impedance and phase angle in a resistive and capacitive circuit.
5. How to determine impedance and phase angle in a circuit containing R, L, and C.

   NavPers 10170, pages 190 to 196
   NavPers 10622-B, pages 255 to 257
6. How Ohm's Law is used in a-c series circuits.
7. How to compute power factor in an a-c circuit.

C. You will acquire skill in:

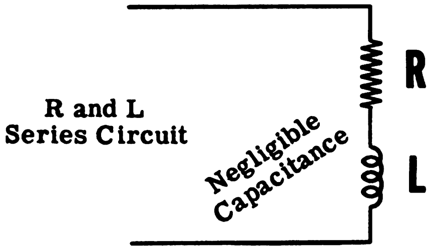
1. Applying Ohm's Law to a-c series circuits.
2. Using vectors to find circuit impedance.

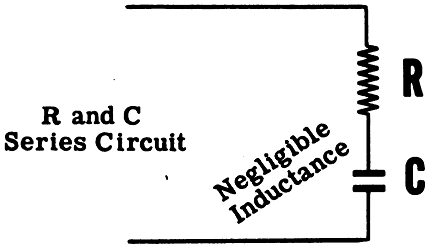
A-C SERIES CIRCUIT COMBINATIONS

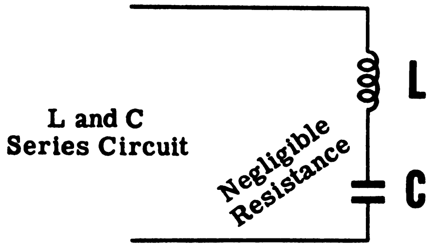
Various combinations of R, L, and C may be used to form a-c series circuits. If two factors are negligible, the circuit may consist of only R, only L, or only C. However, if only one factor is negligible, as is the case in many a-c series circuits, it may consist of R and L, R and C, or L and C. If no factors are negligible, the circuit consists of R, L, and C, and all three factors will affect the current flow.

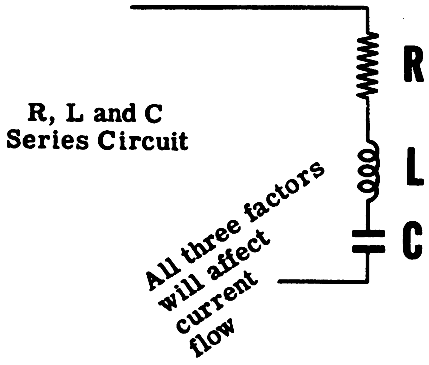
You have found out how R, L, and C individually affect a-c current flow, phase angle, and power in a-c circuits containing only one of these factors. Now you will find out how the various combinations of R, L, and C affect a-c series circuits consisting of any two, or of all three, of these factors.

Every electric circuit contains a certain amount of resistance (R), inductance (L), and capacitance (C). Inductance and capacitance cause inductive and capacitive reactance (X_L and X_C), which opposes the flow of a-c current in a circuit, so that a-c circuits contain three factors which oppose current flow: (R, X_L, and X_C). For a given circuit any of these factors may be so negligible that it can be disregarded.









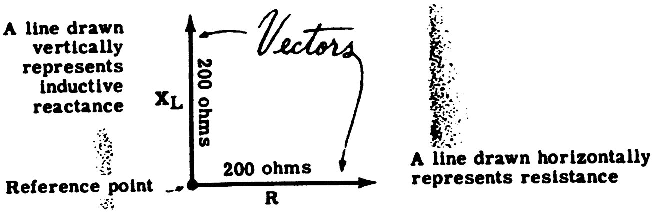
RESISTIVE AND INDUCTIVE SERIES CIRCUITS

When resistance and inductance are connected in series, the total opposition to the current, flow is due to two factors--resistance and inductive reactance--both expressed in ohms. However, the total opposition is not found by adding these two values directly. Inductive reactance causes current to lag the voltage by 90 degrees, while for pure resistance the voltage and current are in phase. Thus, the effect of inductive reactance as opposed to the effect of resistance is shown by drawing the two values at right angles to one another.

For example, suppose your series circuit consists of 200 ohms of resistance in series with an inductance having an inductive reactance of 200 ohms at the frequency of the a-c voltage source. The total opposition to current flow is not 400 ohms but, instead, is equal to approximately 283 ohms. This value of total opposition, called "impedance", is obtained by using a method of addition called "vector addition."

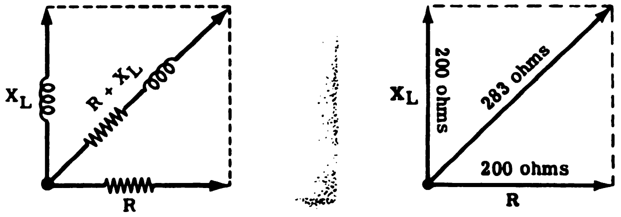
To add 200 ohms of resistance and 200 ohms of inductive reactance, a horizontal line is drawn to represent the 200 ohms of resistance. The end of this line, which is to the left, is the reference point, and the right end of the line is marked with an arrow to indicate its direction. To represent the inductive reactance, a vertical line is drawn upward from the reference point. Since X_L and R are each 200 ohms, the horizontal and vertical lines are drawn equal to each other in length. These lines are called "vectors."

REPRESENTING R AND X_L AS VECTORS

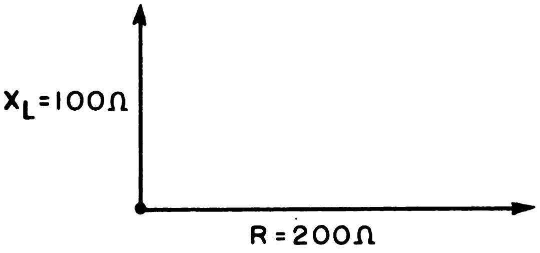

A line drawn vertically represents inductive reactance
X_L
200 ohms
Vectors
200 ohms
R
Reference point
A line drawn horizontally represents resistance

To complete the addition, a parallelogram is completed as shown. The diagonal of this parallelogram represents the impedance Z, the total opposition to current flow of the R and L combination. Using the same scale of measure, this value is found to be 283 ohms.

COMBINING VECTORS R AND X_L TO FIND THE IMPEDANCE

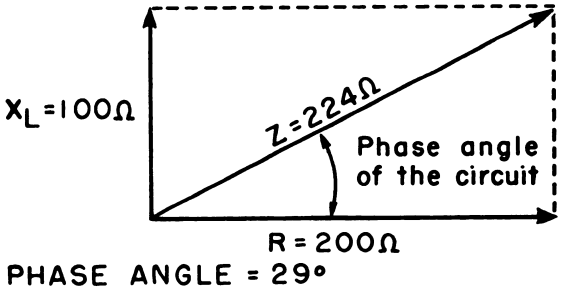


If the resistance and inductance values of a series circuit containing R and L are known, the impedance can be found by means of vectors. First, the inductive reactance X_L is computed by using the formula $X_L=2(3.14)fL$ to obtain the value of X_L in ohms. Then the vectors representing R and X_L are drawn to scale. A common reference point is used with the resistance vector R drawn horizontally to the right, and the inductive reactance vector X_L drawn upward, perpendicular to resistance vector.



1. Draw the vector R horizontally to the right from the common reference point.
2. Draw the vector X_L vertically from the common reference point.

Next, the parallelogram is completed, using dotted lines, and the diagonal is drawn between the reference point and the intersection of the dotted lines. The length of the diagonal represents the value of the impedance Z in ohms.

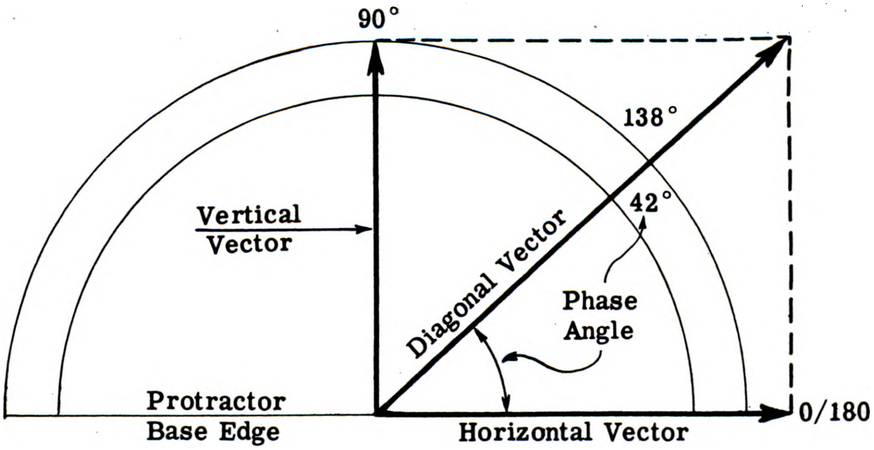


3. Draw intersecting lines parallel to R and X_L to complete the parallelogram.
4. Draw the diagonal of the parallelogram between the intersection of the dotted lines and the reference point.
5. Measure the length of Z on the same scale used for R and X_L to find the value of Z in ohms.

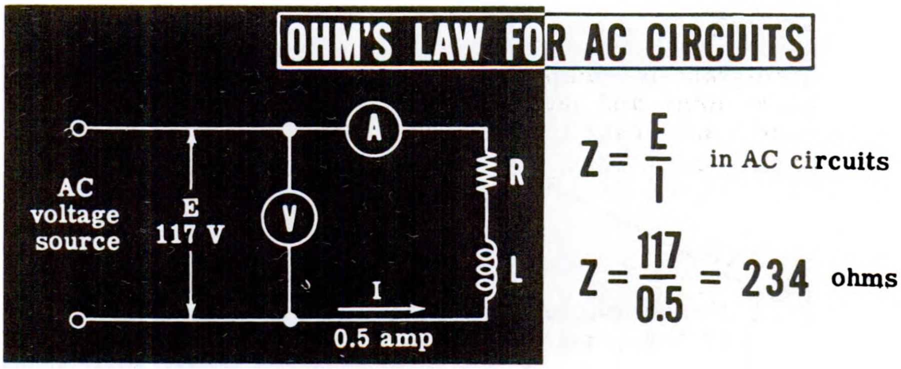
In addition to showing the value of the circuit impedance, the vector solution also shows the phase angle between the circuit current and voltage. The angle between the impedance vector Z and the resistance vector R is the "phase angle" of the circuit in degrees. This is the angle between the circuit voltage and current.

A protractor is an angle-measuring device utilizing a semicircular double scale marked off in degrees.

To measure the phase angle of a vector relative to a reference line, the horizontal edge of the protractor is lined up with horizontal reference vector and the protractor vertical line is lined up with the vertical vector. The degree point at which the diagonal vector intersects the semicircular scale is the phase angle of the diagonal vector. The angle is read between zero and 90 degrees, because the phase angle will never be less than zero or greater than 90 degrees.



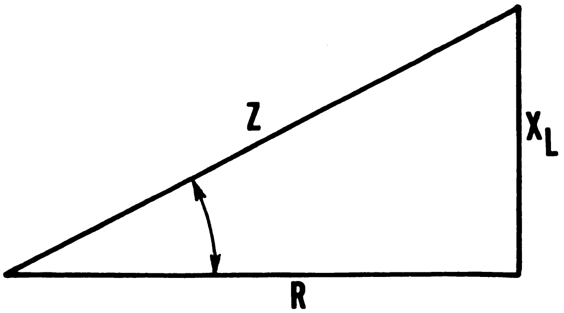
Ohm's Law for a-c circuits may also be used to find the impedance Z for a series circuit. In applying Ohm's Law to an a-c circuit, Z is substituted for R in the formula. Thus, the impedance Z is equal to the circuit voltage E divided by the circuit current I. For example, if the circuit voltage is 117 volts and the current is 0.5 ampere, the impedance Z is 234 ohms.



If the impedance of a circuit is found by applying Ohm's Law for a-c, and the value of R is known and X_L is unknown, the phase angle and the value of X_L may be determined by using vectors.

You have already learned how to calculate (by Ohm's Law) the impedance of a series circuit which is composed of a coil and a resistor, and which is connected to an a-c voltage source. You will now learn how to calculate the impedance of such a circuit without the use of Ohm's Law, and without making measurements.

Assume, for this problem, that the inductive reactance X_L is 4 ohms and that the resistance is 3 ohms. The formula for finding the impedance in the circuit described is as follows:



$$Z = \sqrt{R^2 + X_L^2}$$

Because you may not be familiar with the "square root" sign ($\sqrt{\ }$), and the "square" signs which are in position at the top right of the symbols for resistance and inductive reactance, these symbols or signs are explained below.

A simple way of showing mathematically that a number is to be multiplied once by itself, or "squared," is to place a numeral 2 at the upper right of the number in question. So that

$$3^2 = 3 \times 3, \text{ or } 9$$

$$5^2 = 5 \times 5, \text{ or } 25$$

$$4^2 = 4 \times 4, \text{ or } 16$$

$$\text{and } 12^2 = 12 \times 12, \text{ or } 144, \underline{\text{etc}}.$$

The square root sign, or $\sqrt{\ }$, indicates that you are to break down the enclosed figure to find a number which, when multiplied by itself, results in the original enclosed figure. Consider the problem of finding the square root of 144, shown mathematically, $\sqrt{144}$. What number multiplied by itself results in 144? The answer, of course, is 12. So that

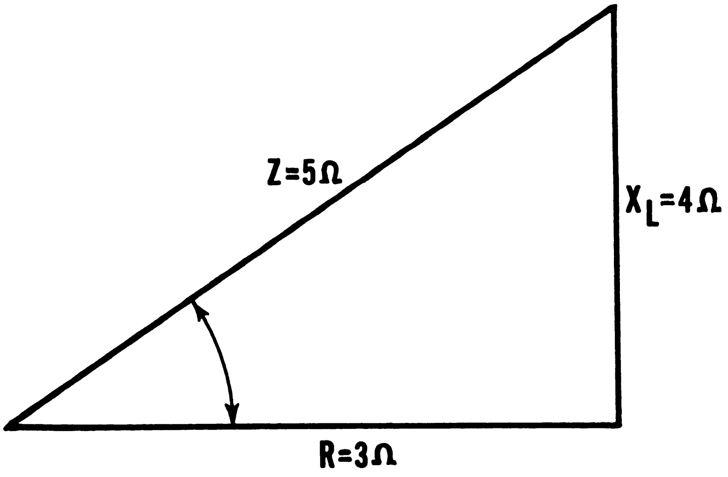
$$\sqrt{144} = 12,$$

$$\sqrt{36} = 6,$$

$$\sqrt{25} = 5,$$

$$\sqrt{9} = 3, \text{ etc.}$$

The formula for impedance ($Z = \sqrt{R^2 + X_L^2}$) then, indicates that you must "square" the values for R and X_L, add the two resultant figures, and take the square root of the total, in order to find the impedance, Z.



$$Z = \sqrt{R^2 + X_L{}^2}$$

By substitution

$$Z = \sqrt{3^2 + 4^2} = \sqrt{9 + 16} = \sqrt{25} = 5$$

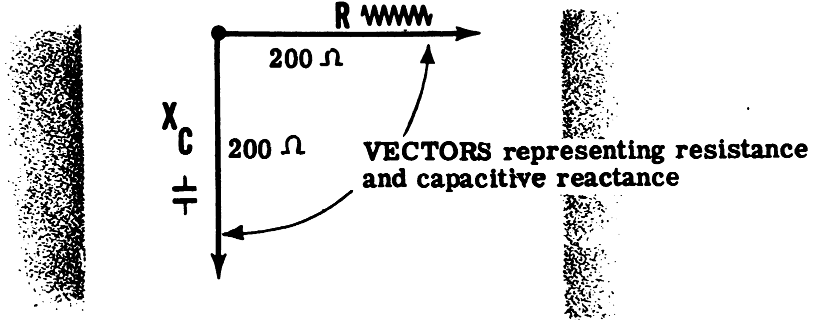
More often than not, the number enclosed by the square root symbol does not permit a simple answer without decimals. In that event it is necessary to find the square root which is closest to the desired numeral within the limits outlined by the instructor. For example, the instructor may elect to accept as correct an impedance value of 5 ohms even though the original figure required that the square root of 30 be found. (The $\sqrt{30}$ is actually equal to 5.47.) There are, of course, methods for finding accurate square root answers but these need not be dealt with here.

RESISTIVE AND CAPACITIVE SERIES CIRCUITS

If your a-c series circuit consists of resistance and capacitance in series, the total opposition to current flow (impedance) is due to two factors, resistance and capacitive reactance. The action of capacitive reactance causes the current in a capacitive circuit to lead the voltage by 90 degrees, so that the effect of capacitive reactance is at right angles to the effect of resistance. While the effects of both inductive and capacitive reactance are at right angles to the effect of resistance, their effects are exactly opposite--inductive reactance causing current to lag and capacitive reactance causing it to lead the voltage. Thus the vector X_C, representing capacitive reactance, is still drawn perpendicular to the resistance vector, but is drawn down rather than up from the zero position.

The impedance of a series circuit containing R and C is found in the same manner as the impedance of an R and L series circuit. For example, suppose that in your R and C series circuit R equals 200 ohms and X_C equals 200 ohms. To find the impedance, the resistance vector R is drawn horizontally from a reference point. Then a vector of equal

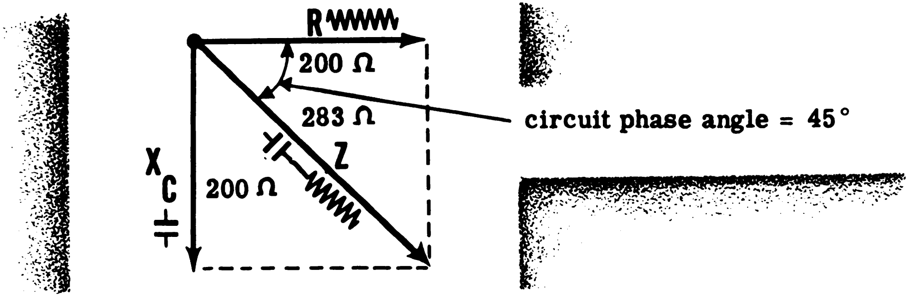
REPRESENTING R AND X_C AS VECTORS



length is drawn downward from the reference point at right angles to the vector R. This vector X_C represents the capacitive reactance and is equal in length to R since both R and X_C equal 200 ohms.

To complete the vector solution, the parallelogram is completed and a diagonal drawn from the reference point. This diagonal is the vector Z and represents the impedance in ohms (283 ohms). The angle between the vectors R and Z is the phase angle of the circuit, indicating the amount in degrees that the current leads the voltage.

COMBINING VECTORS R AND X_C TO FIND THE IMPEDANCE

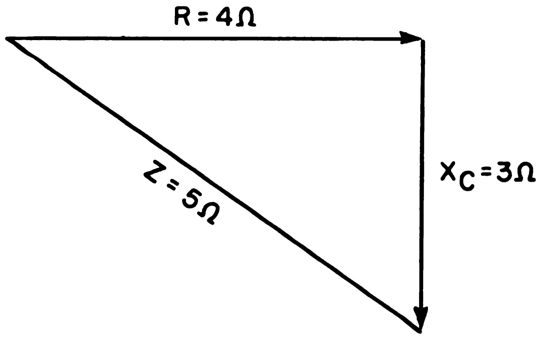


R and C series circuit impedances can be found by using the vector solution, by application of Ohm's Law, or by application of the formula: $Z = \sqrt{R^2 + X_C^2}$. To find impedance Z by using the vector solution, you should perform the steps outlined:

1. Compute the value of X_C by using the formula $X_C = \frac{1}{2\pi f C}$. In this formula 2π is a constant equal to 6.28, f is the frequency in cycles per second, and C is the capacitance in farads.
2. Draw vectors R and X_C to scale, using a common reference point for the two vectors. R is drawn horizontally to the right from the reference point, perpendicular to the resistance vector R.
3. Using dotted lines, a parallelogram is completed and a diagonal drawn from the reference point to the intersection of the dotted lines. The length of this diagonal represents the impedance Z as measured to the same scale as that used for R and X_C. The angle between the vectors R and Z is the phase angle between the circuit current and voltage.
4. Measure the angle in degrees with a protractor.

You can also use Ohm's Law ($Z = E$) to find Z. After measuring the circuit current and voltage, the impedance in ohms can be found by dividing the voltage by the current. For example, if the circuit voltage is 117 volts and 0.1 ampere of current flows through an a-c series circuit consisting of R and C, the impedance is 117 ohms ($117 \div 0.1 = 117$ ohms).

Finally you can use the formula: $Z = \sqrt{R^2 + X_C^2}$. This formula is solved in the same manner as for an R and L series circuit.



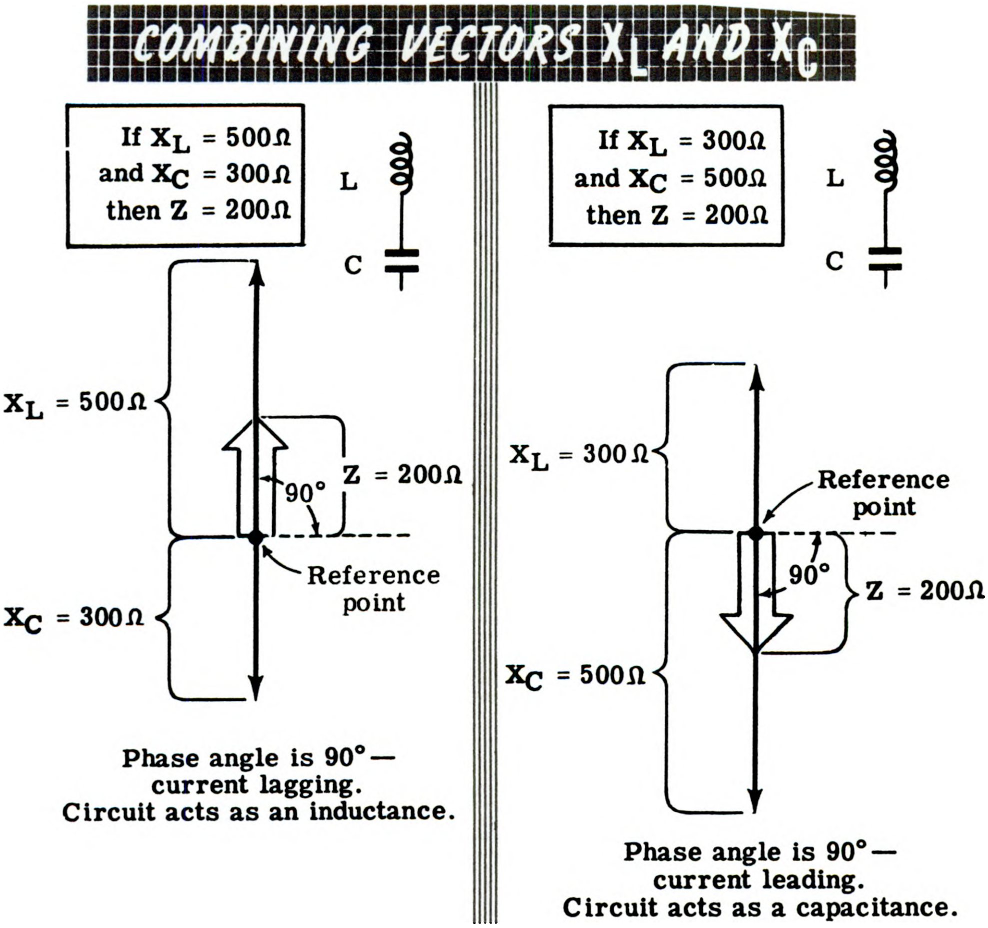
$$Z = \sqrt{R^2 + X_C^2}$$
$$Z = \sqrt{4^2 + 3^2}$$
$$Z = \sqrt{4 \times 4 + 3 \times 3}$$
$$Z = \sqrt{16 + 9}$$
$$Z = \sqrt{25}$$
$$Z = 5\,\Omega$$

INDUCTIVE AND CAPACITIVE SERIES CIRCUITS

In a-c series circuits consisting of inductance and capacitance, with only negligible resistance, the impedance is due to inductive and capacitive reactance only. Since inductive and capacitive reactances act in opposite directions, the total effect of the two is equal to their difference. For such circuits, Z can be found by subtracting the smaller value from the larger. The circuit will then act as an inductive or a capacitive reactance (depending on which is larger), having an impedance equal to Z. For example, if $X_L = 500$ ohms and $X_C = 300$ ohms, the impedance Z is 200 ohms and the circuit acts as an inductance having an inductive reactance of 200 ohms. If the X_L and X_C values were reversed, Z would still equal 200 ohms, but the circuit would act as a capacitance having a capacitive reactance of 200 ohms.

The relationships of the above examples are shown below. Z is drawn on the same axis as X_L and X_C and represents the difference in their values. The phase angle of the L and C series circuit is always 90 degrees, except when $X_L = X_C$, but whether it is leading or lagging depends on whether X_L is greater or less than X_C. The phase angle is the angle between Z and the horizontal axis.

COMBINING VECTORS X_L AND X_C



Phase angle is 90° —
current lagging.
Circuit acts as an inductance.

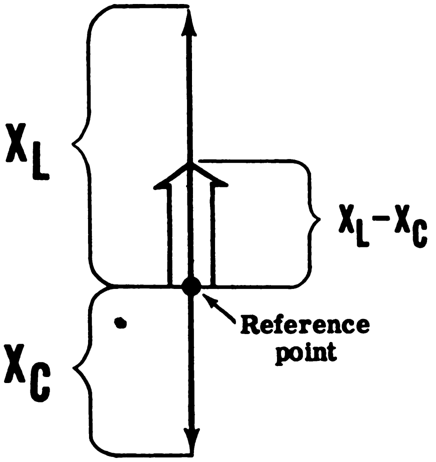
Phase angle is 90° —
current leading.
Circuit acts as a capacitance.

RESISTIVE, INDUCTIVE, AND CAPACITIVE SERIES CIRCUITS

The impedance of a series circuit consisting of resistance, capacitance, and inductance in series depends on three factors: R, X_L and X_C. If the values of all three factors are known, impedance, Z, may be found as follow:

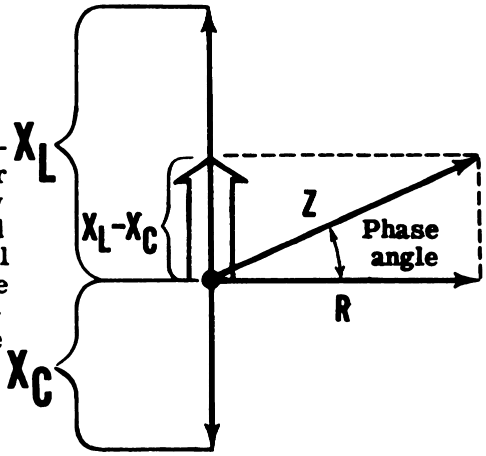
Combine X_L and X_C

1. Draw vectors X_L and X_C to scale vertically from the reference point, and subtract the smaller vector from the larger. The difference is the new vector and should be drawn to scale on the perpendicular axis as shown. Perform a vector addition by subtracting a length equal to the shorter vector from the longer vector.



Combine R and (X_L - X_C)

2. Draw the vector R to scale horizontally, and combine it with the vector obtained in the solution of Step 1 by completing the parallelogram and drawing the diagonal. This diagonal is the vector Z, representing the circuit impedance. The angle between the vectors R and Z is the circuit phase angle.



COMBINING VECTORS R, X_L AND X_C TO FIND THE IMPEDANCE

You can also find the impedance of the circuit by applying Ohm's Law for a-c circuits, after measuring the circuit current and voltage.

POWER FACTOR

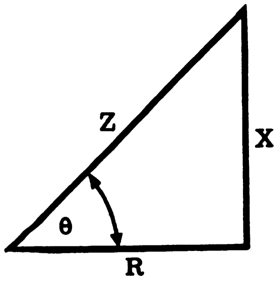
The concept of power, particularly with regard to the calculation of power factors in a-c circuits, will become a very important consideration as the circuits you work with are made more complex. In d-c circuits, the expended power may be determined by multiplying the voltage by the current. A similar relationship exists for finding the amount of expended power in a-c circuits, but certain other factors must be considered. In a-c circuits, the power is equal to the product of voltage and current only when the E and I are in phase. If the voltage and current waves are not in phase, the power used by the circuit will be somewhat less than the product of E and I.

A review of the following principles (most of which you already know) will be helpful later on in the discussion.

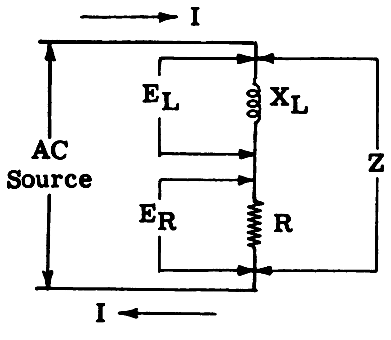
1. Power is defined as the rate of doing work.
2. A watt is the unit of electrical power.
3. Apparent power is the product of volts and amperes in an a-c circuit.
4. True power is the amount of power actually consumed by the circuit.
5. True power is equal to apparent power if the voltage and current are in phase.
6. True power is equal to zero if the voltage and current are out of phase by 90 degrees.
7. True power is equal to the apparent power multiplied by a figure called the "cosine of the phase angle." (This term will be explained shortly.)
8. The cosine of the phase angle is called the "power factor" and is often expressed as a decimal or percentage.

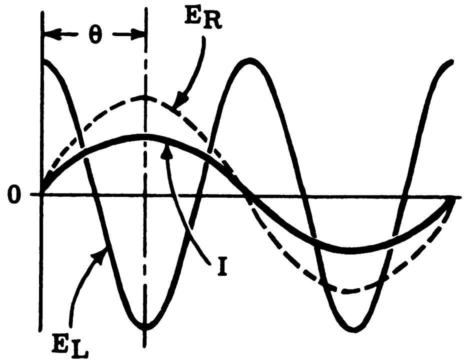
The power factor is important because it converts apparent power to true power. It is this true power, the kind that actually does work in the circuit, which will interest you most.

The cosine of the phase angle, or power factor, is explained with the help of the familiar impedance triangle diagram. The resistive component forms the base. The reactive component (X) forms the right angle with the base, and the third side called the "hypotenuse" is the resultant impedance (Z). The angle formed by the R and Z sides of the impedance triangle is called by the Greek letter O (theta). The angle O originally refers to the phase angle difference between the voltage across the resistor and the voltage across the coil in the diagram at the bottom of this page.

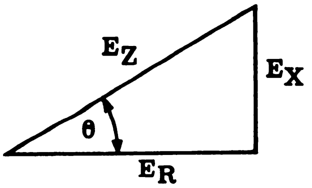


Theoretically, the voltage across the coil leads the current through the circuit by a phase angle of 90 degrees. E_L leads the voltage across the resistor because E_R is in phase with I.





In practical circuits, a phase angle of 90 degrees is an impossibility because every coil (and wire) has some resistance, however small. It is this resistance, and the resistance placed in the circuit by design, which reduces the phase angle to something less than 90 degrees. Consider the voltage triangle of the circuit above. Each of the voltages noted may also be expressed as the product of the current times the resistance, reactance,



$E_Z = IZ$
$E_X = IX$
$E_R = IR$

or impedance, as the case may be. The term, cosine of the phase angle, refers to a ratio of E_R to E_Z and is expressed mathematically as

$$\text{Cos } \theta = \frac{E_R}{E_Z}$$

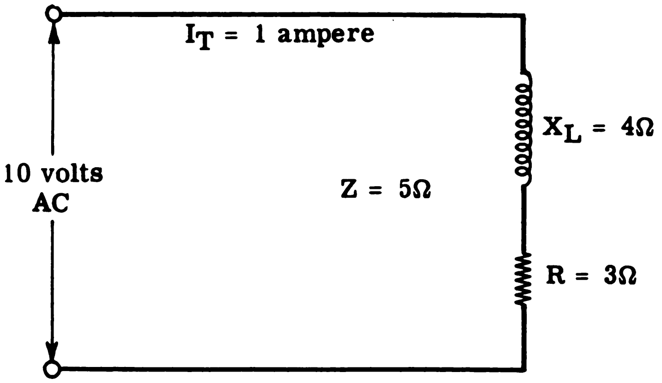
This formula is used just as well where impedance, resistance, and reactance are the prime considerations, because

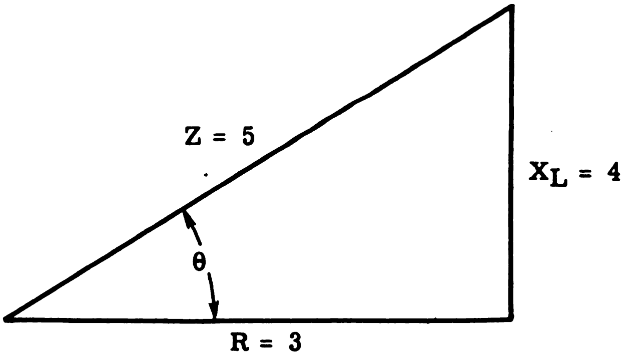
$$\text{Cos } \theta = \frac{E_R}{E_Z} = \frac{IR}{IZ} = \frac{R}{Z}$$

You now know all of the factors mentioned in points 7 and 8 on the previous page. The formula for true power should, therefore, present no difficulties. This formula is expressed mathematically as

$$P = E^{I} \text{ Cos } \theta \text{ or, Cos } \theta = \frac{P}{EI} \text{ or, } EI = \frac{P}{\text{Cos } \theta}$$

Suppose that you wish to find the amount of power expended (true power) in a circuit where the impedance is 5 ohms, the resistance is 3 ohms, and the inductive reactance is 4 ohms. The impressed voltage is volts a-c, and the current is one ampere.





E = 10 volts, AC
I = 1 amp, AC

The formula for true power is $P = EI \cos\theta$. With reference to the impedance triangle, the $\cos\theta$ is equal to the ratio of R divided by Z, or

$$\cos\theta = \frac{R}{Z} = \frac{3}{5} = .60 \text{ or } 60\%$$

Substituting in the formula for true power

$$P = EI \cos\theta$$
$$P = 10 \times 1 \times .6$$
$$P = 6 \text{ watts of power expended}$$

The components in the circuit must be chosen of such size that they will be able to dissipate six watts of power at the very minimum, or burnout will occur.

JOB SHEET NO. 24

1. The total circuit opposition to current flow is called

   ________________________________.

2. To find total opposition to current flow in a series a-c circuit, the resistance and

   reactance must be ____.

3. The ratio of reactance to resistance will determine

   ____.

4. If X_L is greater than X_C, in a series a-c circuit, the circuit will be

   ________________________________.

5. Impedance is equal to ________________ divided by ________________.

6. True power is equal to apparent power times ____________________.

7. Solve for the listed unknown values in the following problem.

   Given:
   Applied voltage = 100v a-c
   R = 6 Ω
   XL = 8 Ω

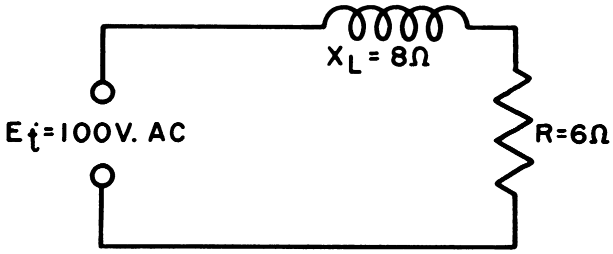
   Find:
   Z = ______________

   I = ______________

   Power factor = ______________

   True Power = ______________

   Phase Angle = ______________



8. Solve for the listed unknown values in the following problem.

Given:
Applied voltage = 120v a-c
R = 12
X_C = 9

Find:
Z = ________________

I = ________________

Phase Angle = ________________

Power Factor = ________________

True Power = ________________

9. A 2K resistor, lmfd condenser and a 10h choke are connected in series with a 60-cycle source voltage of 92 volts. Draw a diagram of the circuit and solve for the following:

a. X_C = ________________.

b. X_L = ________________.

c. Z = ________________.

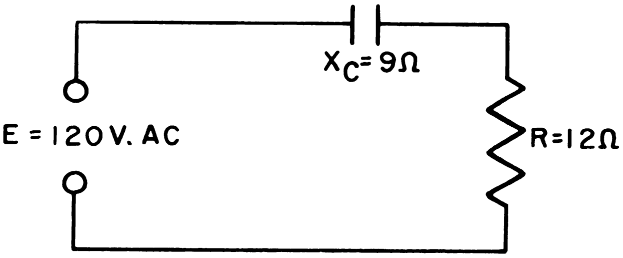
d. I = ________________.

e. Power factor = ________________.

f. Phase angle = ________________.

g. True power = ________________.

h. Does the current lead or lag the voltage? ________________.



SECTION V

SAFETY PRECAUTIONS

Topic No.	Topic Title	Sheet
1.	General Safety	V-1-1
2.	Causes of Accidents	V-2-1
3.	Handling of Tools	V-3-1
4.	Working with Machinery, Solvents, and Paint	V-4-1
5.	Electrical Work	V-5-1
6.	Operation of Fire Control Equipment	V-6-1
7.	First Aid	V-7-1

SECTION V

TOPIC 1

GENERAL SAFETY

A. You have learned:	References:
1. About Fire Control in general	
2. About electricity fundamentals	
3. About d-c circuits	
4. About a-c circuits	
B. You are learning:	
1. What Section V contains	
2. Aims of safety precautions	NavPers 10164-A, pages 267 and 268 OPNAV-34P1, pages III, 3 to 5
3. Administration of safety precautions	NavPers 10164-A, page 268 OPNAV-34P1, pages 3 to 5, 415 to 416
4. Responsibilities of personnel	OPNAV-34P1, pages 3 to 5, 415 to 416

INTRODUCTION TO SECTION V

Topic 1 consists of a study of the purpose of safety precautions and the responsibility of various personnel.

Topic 2 covers causes of accidents.

Topic 3 covers precautions to be observed when using hand tools and portable power tools.

Precautions to be observed when working with machinery, paints, and solvents are taken up in Topic 4.

Hazards of electrical work and precautions to be observed are discussed in Topic 5.

Topic 6 covers the operation of fire control equipment.

First Aid treatment of electrical shock and burns is covered in Topic 7.

If you glance through the rest of Section V, you will notice that it contains numerous blank spaces. This section is written so that you can fill in the blanks during the discussions. This will aid you in maintaining proper and complete notes. Be sure to fill in all spaces properly and completely. Don't hesitate to ask the instructor for help if you are in doubt as to an answer.

GENERAL SAFETY

The two principal aims of safety precautions are:

a. ______________________________

b. ______________________________

When necessary in local and emergency situations, instructions or notices to supplement and augment Navy Department Precautions may be issued by:

a. ______________________________

b. ______________________________

c. ______________________________

Effective and continuous accident prevention programs shall be conducted by ______________________________.

Operating procedures and work methods shall be adopted which do not expose personnel unnecessarily to ______________________________.

Instruction in appropriate safety precautions shall be given by all commands, and disciplinary action taken in case of ______________________________.

Responsibility for the safety of personnel is vested in the ______________________________.

To insure that all prescribed precautions are understood and strictly enforced, the commanding officer may ______________________________.

The commanding officer shall issue new precautions or supplement prevailing ones in the manner and degree that he deems necessary for the protection of personnel whenever

a. ______________________________

b. ______________________________

It is the responsibility of supervisory personnel to ______________________________.

Supervisory personnel are under orders from and responsible to ______________________________.

The safety responsibilities of operating personnel are:

a. ____

____

b. ____

____

c. ____

____

d. ____

____

e. ____

SECTION V

TOPIC 2

CAUSES OF ACCIDENTS

A. You have learned:

1. About Fire Control in general
2. About electricity fundamentals
3. About d-c circuits
4. About a-c circuits
5. About safety in general

B. You are learning:

1. The most frequent causes of accidents

References:

NavPers 10164-A, pages 268 to 270
OPNAV-34P1 pages 365 to 385
NavShips-250-660-42 pages 1 to 6

CAUSES OF ACCIDENTS

The principle causes of accidents are:

1. Ignorance of safety precautions
   Due to:
   a. Lack of individual initiative.
   b. Lack of an adequate safety education program.

2. ____
   Due to:
   a. ____
   b. ____

3. ____
   Due to:
   a. ____

4. ____

5. ____

6. ____
   Due to:
   a. ____
   b. ____
   c. ____

SECTION V

TOPIC 3

HANDLING OF TOOLS

A. You have learned:	References:
1. About Fire Control in general	
2. About electricity fundamentals	
3. About d-c circuits	
4. About a-c circuits.	
5. About safety in general	
6. About the causes of accidents	
B. You are learning:	
1. Precautions to be observed while handling hand tools.	NavPers 10164-A, pages 270 and 271 OPNAV 34 P1, pages 327 to 331
2. Precautions to be observed while handling power tools.	NavPers 10164-A, pages 270 and 271 OPNAV 34 P1, pages 332 to 333 NavShips-250-660-42, pages 17 to 37

GENERAL ITEMS:

1. Improper handling of tools can cause:

   a. ____.

   b. ____.

   c. ____.

2. Never leave tools adrift in dangerous spaces.

3. Proper stowage facilities for tools should always be ____________________

   and ____________________.

4. Tools must conform to ____________________________________.

5. Around explosives, use only ______________________________ tools.

6. All tools must be:
   a. In good repair

   b. Used only by ____________________.

7. The condition of tools should be checked ____________________________.

HANDLING OF TOOLS

SAFE USE OF HAND TOOLS

1. Before using any tool, it should always be checked to see that it is in ____________ ____________.

2. It is important that only the ____________ for the job be used.

3. Tools should always be held the safest way possible.

4. When working with sharp hand tools, always work so that the tool is moved or thrust ____________.

5. Whenever chipping, buffing, or grinding, always wear ____________.

6. If it is necessary to work on high-voltage electrical equipment while in an energized state,
   a. wear ____________
   b. use tools with ____________
   c. stand on ____________

7. Never use hand tools around ____________ unless absolutely necessary.

SAFE USE OF POWER TOOLS

1. The casings of all electrically driven tools should be ____________ ____________.

2. Power tools should be tested periodically by qualified personnel for
   a. ____________.
   b. ____________.

3. Power tools should not be used near ____________ ____________.

4. Seriously damaged cords of power tools should be ____________.

5. Do not wear loose or torn clothing while using ____________ ____________.

SECTION V

TOPIC 4

WORKING WITH MACHINERY, SOLVENTS, AND PAINT

A. You have learned:	References:
1. About Fire Control in general	
2. About electricity fundamentals	
3. About d-c circuits	
4. About a-c circuits	
5. About safety in general	
6. About the causes of accidents	
7. About the precautions to be observed when handling tools.	
B. You are learning:	
1. Precautions to be observed before operating machinery	NavPers 10164-A, page 272 OPNAV 34 P1, pages 275 to 280
2. Precautions to be observed while operating machinery	OPNAV 34 P1, pages 275 to 280
3. Precautions to be observed while using cleaning solvents and paint.	OPNAV 34 P1, pages 289, 298, 302 to 305

READYING MACHINERY FOR OPERATION

1. Machinery is to be operated by ____.

2. Areas around machines should be kept clear of obstructions and in non-slippery conditions.

3. Machines should be kept ______________________________.

4. When using portable electric equipment around machines, keep all electrical cords clear of moving parts.

5. Snug-fitting clothing should be worn when working around machinery.

6. Goggles or face shields should be worn when ___________________________________
____.

7. Machine guards must be kept in position at all times unless removal is authorized for repairs or cleaning.

8. All needed repair to machinery should be reported.

9. Repairs are to be made only by ____.

10. Do not repair, oil, or clean machinery while it is

    ______________________________.

11. Shut off power to machines during repairs or adjustment and

    ______________________________to the switch.

12. Machines with frayed or otherwise deteriorated insulation should

    ______________________________.

OPERATING MACHINERY

Seven important precautions to remember when operating machinery are:

1. Keep the working area ______________________________

   ______________________________.

2. Never adjust______________________________.

3. Do not apply tools______________________________.

4. Do not use part of the body______________________________

   ______________________________.

5. Never leave running machines______________________________.

6. Do not distract______________________________.

7. Never toss or throw an object at another person.

CLEANING SOLVENTS AND PAINTS

1. When using solvents or paints, it is very important that the work area is

   ______________________________.

2. Most solvents and paints are to be stowed separately because they are

   ______________________________.

3. When painting aloft or overside______________________________
   must always be worn.

4. The types of cleansers and solvents used in fire control, precautions about each, and treatment in case of contact, are:
   a. Acids
      Precautions to remember about acids:

      (1)______________________________.

      (2)______________________________.

      (3)______________________________.

(4) ____

____.

(5) ____

(6) ____

____.

Treatment in case of contact:

(1) ____

____.

b. Alcohols

Precautions to remember about alcohols:

(1) ____

(2) ____

(3) ____

(4) ____

Treatment in case of contact:

(1) ____

____

____

c. Ketones

Precautions to remember about ketones:

(1) ____

(2) ____

(3) ____

(4) ____

d. Chlorinated Compounds

Precautions to remember about chlorinated compounds

(1) ____

(2) ____

(3) ____

(4) ____

SECTION V

TOPIC 5

ELECTRICAL WORK

A. You have learned: References:

1. About Fire Control in general.
2. About electricity fundamentals.
3. About d-c circuits.
4. About a-c circuits.
5. About safety in general.
6. About the causes of accidents.
7. About the precautions to be observed when handling tools.
8. About the precautions to be observed when working with machinery, solvents and paint.

B. You are learning:

1. Some general precautions for electrical work.	NavPers 10164-A, pages 272 and 273 OPNAV 34 P1, pages 369, 365
2. Causes and prevention, of electric shock.	NavPers 10164-A, pages 272-273 NavShips 250-660-42
3. Precautions to be observed when adjusting, testing, and repairing electrical circuits.	NavPers 10164-A, pages 272-273 OPNAV 34 P1, pages 383; 373-375; 365
4. Safety devices used in electrical circuits.	OPNAV 34 P1, pages 365, 382, 415, 375-377; 370-371

GENERAL PRECAUTIONS

Working on electrical equipment aboard ship is far more hazardous than ashore due to the presence of salt water and the steel hull of the ship.

Officially compiled statistics show that more than half of all fatalities from electrical work were caused by circuits carrying 115 volts or less. Also, that portable electric equipment was responsible for more than a third of the fatalities.

More fatal accidents are caused by "human failure" than by "equipment failure."

ELECTRIC SHOCK--CAUSES AND PREVENTION

Whenever current flows through a human body there will be electric shock. Two conditions must be satisfied for current to flow through a man, namely:

1. The man must form part of a closed circuit in which current can flow.
2. Somewhere in the closed circuit there must be an emf or difference potential to cause current flow.

Investigation has shown that if 100 milliamperes of 60-cycle a-c current flows through the average human body for one second or more, the shock will be fatal.

Causes of electrical shock are:

1. Equipment failures
   Due to:
   - a. ____________________
   - b. ____________________
2. Human failures
   Due to:
   - a. ____________________
   - b. ____________________
   - c. ____________________
   - d. ____________________
     ____
   - e. ____________________

Electrical shock can be prevented by:

- a. ____________________
  ____
  ____
- b. ____________________
  ____
- c. ____________________
  ____
  ____

TESTING, ADJUSTING, AND REPAIRING

The principle precautions to be observed when testing, adjusting, or repairing electrical equipment and circuits are;

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________________________

11. ______________________________

12. ______________________________

13. ______________________________

14. ______________________________

15. ______________________________

SAFETY DEVICES

The function of safety devices used with electrical circuits are:

1. Circuit breakers

____

____

2. Fuses

____

____

3. Relays--Voltage overload

____

____

4. Interlocks

____

____

5. Ground-type plugs and receptacles

____

____

6. Ground cords

____

____

7. Class "C" extinguishers

____

____

SECTION V

TOPIC 6

OPERATION OF FIRE CONTROL EQUIPMENT

A. You have learned: References:

1. About Fire Control in general.
2. About electricity fundamentals.
3. About a-c and d-c circuits.
4. About safety in general.
5. About the causes of accidents.
6. About the precautions to be observed when handling tools.
7. About the precautions to be observed when working with machinery, solvents and paints.
8. About the precautions to be observed when doing electrical work.

B. You are learning:

1. Precautions to take before operating Fire Control equipment.	NavPers 10164-A, pages 273 and 274
2. Action to take while operating Fire Control equipment.	NavPers 10164-A, pages 273 and 274; 137 to 148
3. How to secure Fire Control Equipment Safely.	NavPers 10164-A, pages 273 and 274

Three important precautions to observe before operating fire control equipment are:

1. ____

____

2. ____

____

3. ____

____

Four important precautions to observe while operating fire control equipment are:

1. ____

____

2. ____

____

3. ____

____

4. ____

____

Three items to remember when securing fire control equipment are:

1. ____

____

2. ____

____

3. ____

____

SECTION V

TOPIC 7

FIRST AID

A. You have learned: References:

1. About Fire Control in general
2. About electricity fundamentals
3. About a-c and d-c circuits
4. About safety in general
5. About the causes of accidents
6. About precautions to be observed when handling tools
7. About precautions to be observed when working with machinery, solvents, and paints
8. About precautions to be observed when doing electrical work
9. About safe operation of FC equipment

B. You are learning:

1. Treatment for electric shock	NavPers 10164-A, pages 274 to 276
2. Treatment for burns	OPNAV 34 P1, page 367
	NavPers 10164-A, 'pages 277 and 278

ELECTRIC SHOCK--FIRST AID

The first and most important thing to do in case of electric shock is

____

While making preparations to administer first aid you should send

____

If the victim has ceased to breathe or his breathing is extremely weak,

____

Two methods of applying artifical respiration are:

1. ______________________________

2. ______________________________

The Navy approved method of artifical respiration is the ____________________

____ method.

Artifical respiration should be carried on at ____________________________

____.

Keep the victim warm and treat with some type of stimulant (nonalcoholics).

BURNS--FIRST AID

1. Burns are caused by dry heat, such as
   a. ________________________________
   b. ________________________________
   c. ________________________________
2. Scalds are caused by moist heat, such as
   a. ________________________________
   b. ________________________________
3. Treatment for burns and scalds is
   a. ________________________________
   b. ________________________________
   c. ________________________________
   d. ________________________________
   e. ________________________________
   f. ________________________________

Burns caused from alkalies and acids should first be flushed with ______________

______________________________.

SECTION VI

ELECTRICAL MACHINERY

Topic No.	Topic Title	Sheet
1.	Elementary Generators	VI-1-1
2.	Direct Current Generators	VI-2-1
3.	Direct Current Motors	VI-3-1
4.	Transformers	VI-4-1
5.	Alternating Current Motors	VI-5-1
6.	Power Control Devices	VI-6-1
7.	Cables	VI-7-1
8.	Test Equipment	VI-8-1
9.	Synchro Units	VI-9-1

SECTION VI

TOPIC 1

ELEMENTARY GENERATORS

		References:
A.	You have learned:	
	1. The principles of magnetism and how it produces electricity	
	2. The principles of a-c and d-c electricity	
B.	You are learning:	
	1. What section VI contains	
	2. That generators are the major source of electrical power for fire control	NavPers 10622-B, pages 173 and 174.
	3. A review of magnetic fields	NavPers 10622-B, pages 109 to 172
	4. The principle of generator action	NavPers 10622-B, pages 175 to 177
	5. How generators are constructed	NavPers 10622-B, pages 174; 177 to 180
	6. The basic differences between a-c and d-c generators	NavPers 10622-B, pages 180 to 182

INTRODUCTION TO SECTION VI

Topic 1 contains an outline of material contained in section VI, a review of magnetic principles, and the uses and principles of a-c and d-c generators.

Topic 2 contains a detailed description of the construction and characteristics of d-c generators.

Topic 3 contains a description of d-c motors, principle of operation, their uses, classification, and methods of control and maintenance.

Transformer uses, principle of operation, construction, types, and trouble shooting will be covered in Topic 4.

The types of a-c motors, especially three-phase and split-phase operation, will be covered in Topic 5.

A study of switches, fuses, relays, and circuit breakers will be taken up in Topic 6.

Topic 7 contains a study of how cables are classified, constructed, and coded, and cable maintenance.

Topic 8 contains the types, uses, connections, operation, care, and maintenance of test equipment.

Synchro principle of operation, construction, types, alignment, and maintenance will be taken up in Topic 9.

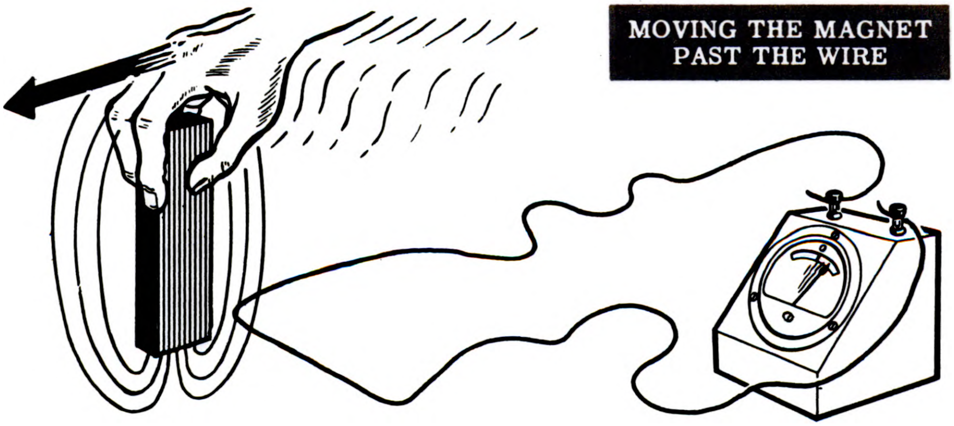
INTRODUCTION TO GENERATORS

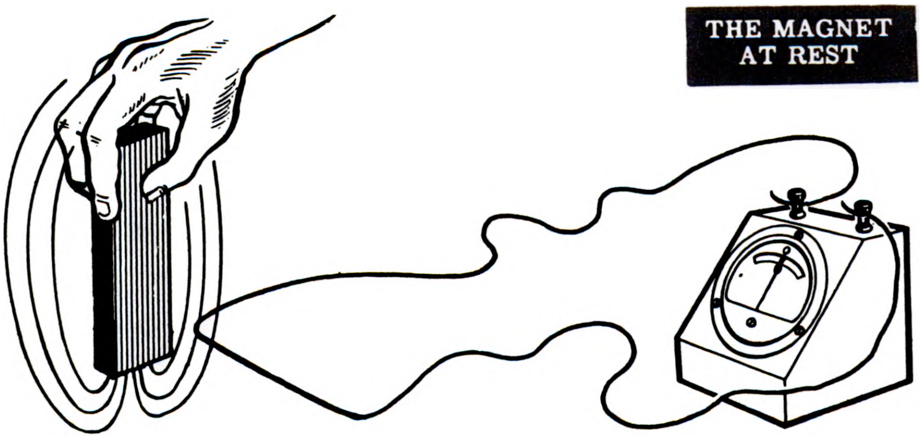
Generators convert ____________________ power to ____________ ________ power.

The source of ship's power is the ____________________ generators, or in case of casualty, the ____________________ generator.

REVIEW OF MAGNETIC FIELDS

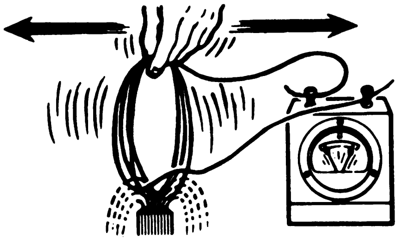
You will recall that electricity can be generated by moving a wire through a magnetic field. When you performed the experiment on magnetism as a source of electricity, you saw that current flowed through a conductor (a wire connected across the terminals of a zero-center meter) when a magnet was moved across the conductor. You found out that as long as there is relative motion between the conductor and the magnetic field, electricity is generated. If there is no relative motion between the conductor and the magnetic field, electricity is not generated. The generated electricity is actually a voltage called an "induced voltage," and the method of generating this voltage by cutting a magnetic field with a conductor is called "induction." You also know that this induced voltage will cause a current to flow if the ends of the conductor are connected through a closed circuit--in this case, the meter.


MOVING THE MAGNET PAST THE WIRE

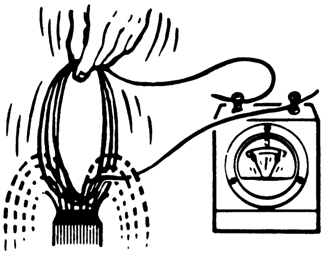

THE MAGNET AT REST

You know that the amount of voltage induced in the wire cutting through the magnetic field depends upon a number of factors. First, if the speed of the relative cutting action between the conductor and the magnetic field increases, the induced emf increases. Second, if the strength of the magnetic field increases, the induced emf increases. Third, if the number of turns cutting through the magnetic field is increased, the induced emf is again increased.

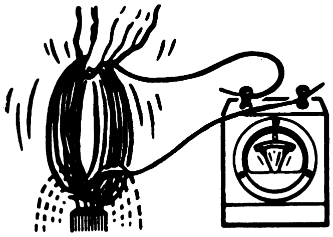
The polarity of this induced emf will be in such a direction that the resultant current flow will build up a field to react with the field of the magnet, and oppose the movement of the coil. This phenomenon illustrates a principle known as "Lenz's Law," which states that in all cases of electromagnetic induction the direction of the induced emf is such that the magnetic field it sets up tends to stop the motion which produces the emf.



... THE SPEED OF CONDUCTOR THROUGH MAGNETIC FIELD



... THE STRENGTH OF MAGNETIC FIELD

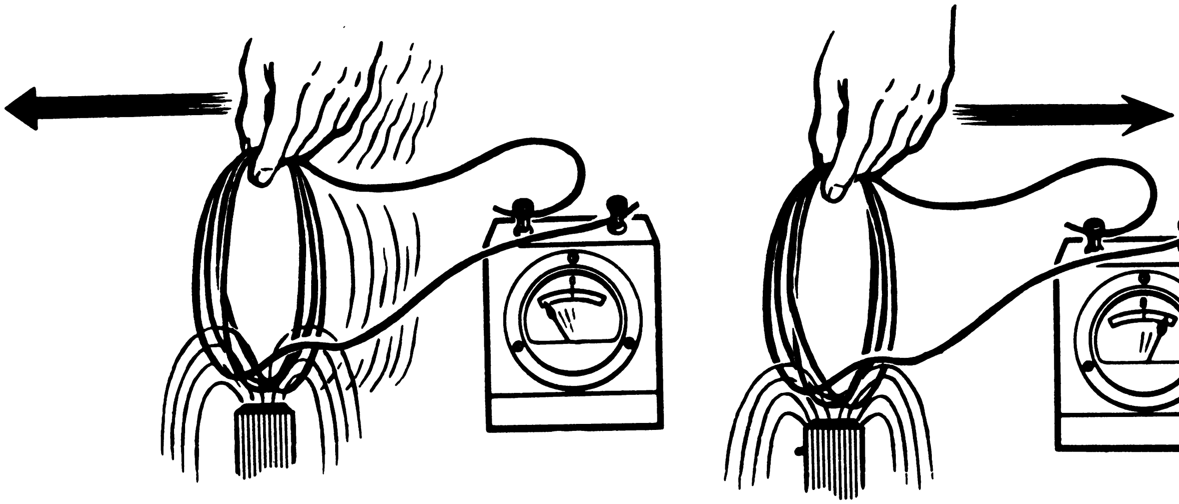


... THE NUMBER OF TURNS

FACTORS WHICH DETERMINE INDUCED EMF STRENGTH

You also know that the direction of the generated current flow is determined by the direction of the relative motion between the magnetic field and the cutting conductor. If the relative motion is toward each other, the current flows in one direction; if the relative motion is away from each other, the current flows in the opposite direction.

DIRECTION OF RELATIVE MOTION DETERMINES DIRECTION OF CURRENT FLOW



To sum up what you already know about electricity from magnetism: (1) Moving a conductor through a magnetic field generates an emf which produces a current flow; (2) the faster the conductor cuts through the field, the more turns there are and the stronger the magnetic field, the greater the induced emf and the greater the current flow; and (3) reversing the direction of movement of the conductor reverses the polarity of the induced emf and therefore reverses the direction of current flow.

SUMMARY

Power drives, radar, electrical meters, motors, generators, automatic switches, and many other kinds of electrical apparatus depend for their operation on electricity and magnetism. In fact, electricity or magnetism alone--one without the other-- is seldom found in a machine. Because magnetism is so important in electricity, the following table reviews the most important terms in this chapter.

Fill in the meanings of the following terms from NavPers 10623-B, pages 133 and 134:

Poles-- ____________________

____

Attraction-- ____________________

____

Repulsion-- ____________________

____

Flux, magnetic field, field of force-- ____________________

____

____

Induction-- ______________________________

____

North pole-- ______________________________

South pole-- ______________________________

____

Permanent magnets-- ______________________________

____

Complete path-- ______________________________

____

Magnetic lines-- ______________________________

____

____

____

Magnetic substances-- ______________________________

____

Nonmagnetic substances-- ______________________________

____

____

Reluctance-- ______________________________

____

Permeability-- ______________________________

Saturation-- ______________________________

____

Retentivity-- ______________________________

____

Residual magnetism-- ______________________________

____

GENERATOR ACTION

State two quantities that determine direction of current flow in a basic generator.

____

____

____

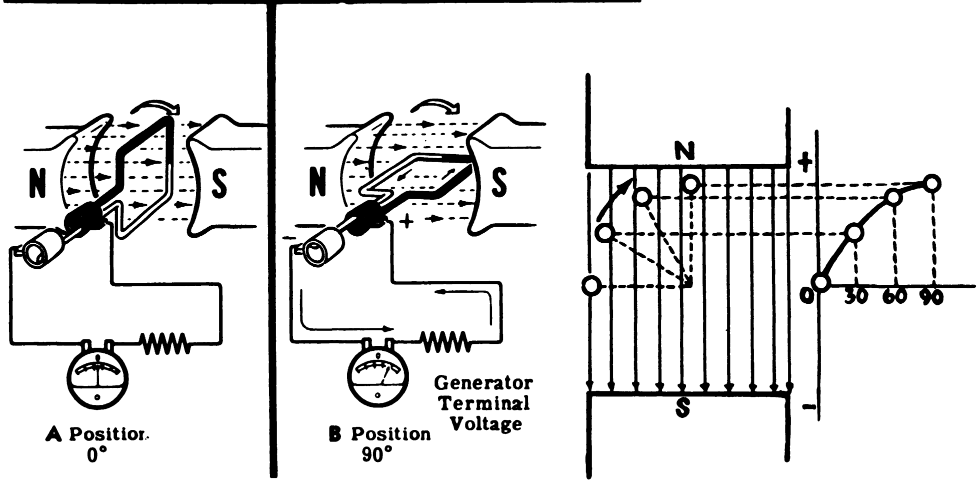
What type voltage is generated inside any generator? ______________________________

____

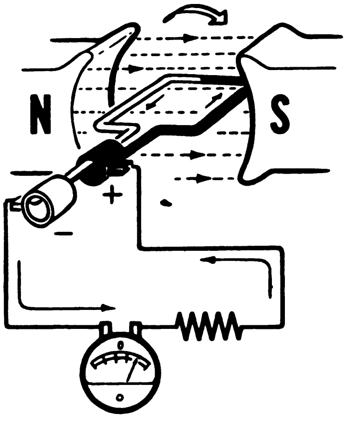
Here is the way the elementary generator works: Assume that the armature loop is rotating in a clockwise direction, and that its initial position is at A (zero degrees). In position A, the loop is perpendicular to the magnetic field and the black and white conductors of the loop are moving parallel to the magnetic field. If a conductor is moving parallel to a magnetic field, it does not cut through any lines of force and no emf can be generated in the conductor. This applies to the conductors of the loop at the instant they go through position A. No emf is induced in them and, therefore, no current flows through the circuit. The current meter registers zero.

As the loop rotates from position A to position B, the conductors are cutting through more and more lines of force until at 90 degrees (position B) they are cutting through a maximum number of lines of force. In other words, between zero and 90 degrees, the induced emf in the conductors builds up from zero to a maximum value. Observe that from zero to 90 degrees the black conductor cuts down through the field while at the same time the white conductor cuts up through the field. The induced emfs in both conductors are therefore in series-adding, and the resultant voltage across the brushes (the terminal voltage) is the sum of the two induced emfs, or double that of one conductor since the induced voltages are equal to each other. The current through the circuit will vary just as the induced emf varies--being zero at zero degrees and rising up to maximum at 90 degrees. The current meter deflects increasingly to the right between positions A and B, indicating that the current through the load is flowing in the direction shown. The direction of current flow and polarity of the induced emf depend on the direction of the magnetic field and the direction of rotation of the armature loop. The waveform shows how the terminal voltage of the elementary generator varies from position A to position B. The simple generator drawing on the right is shown shifted in position to illustrate the relationship between the loop position and the generated waveform.

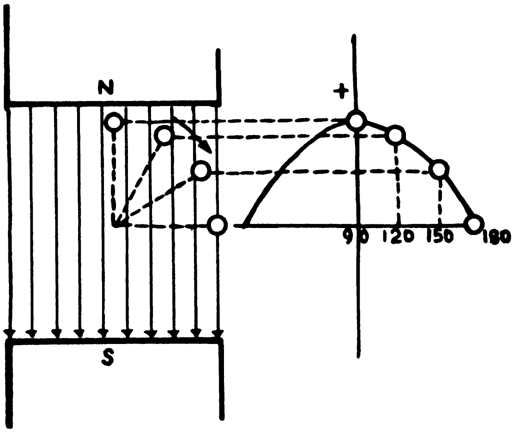
HOW THE ELEMENTARY GENERATOR WORKS

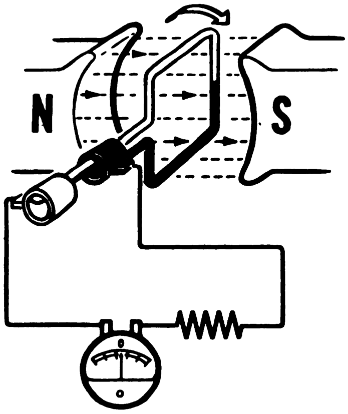


As the loop continues rotating from position B (90 degrees) to position C (180 degrees), the conductors which are cutting through a maximum number of lines of force at position B cut through fewer lines, until at position C they are moving parallel to the magnetic field and no longer cut through any lines of force. The induced emf, therefore, will decrease from 90 to 180 degrees in the same manner as it increased from zero to 90 degrees. The current flow will similarly follow the voltage variations. The generator action at positions B and C is illustrated.



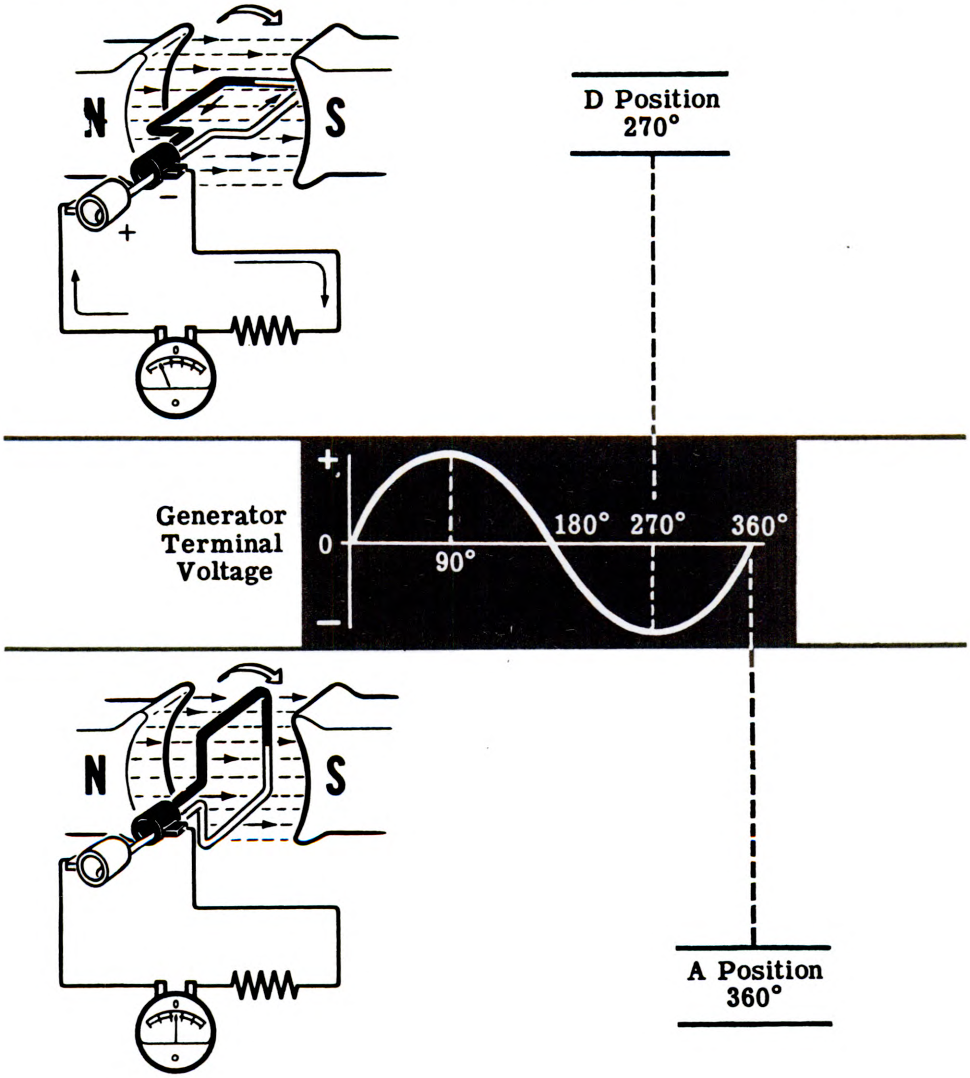
B Position
90°





C Position
180°

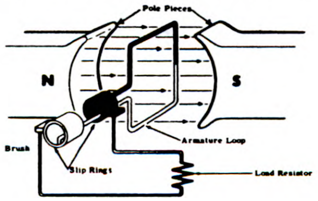
From zero to 180 degrees, the conductors of the loop have been moving in the same direction through the magnetic field and, therefore, the polarity of the induced emf has remained the same. As the loop starts rotating beyond 180 degrees back to position A, the direction of the cutting action of the conductors through the magnetic field reverses. Now the black conductor cuts up through the field, and the white conductor cuts down through the field. As a result, the polarity of the induced emf and the current flow will reverse. From positions C through D back to position A, the current flow will be in the opposite direction than from positions A through C. The generator terminal voltage will be the same as it was from A to C except for its reversed polarity. The voltage output waveform for the complete revolution of the loop is as shown.



GENERATOR CONSTRUCTION

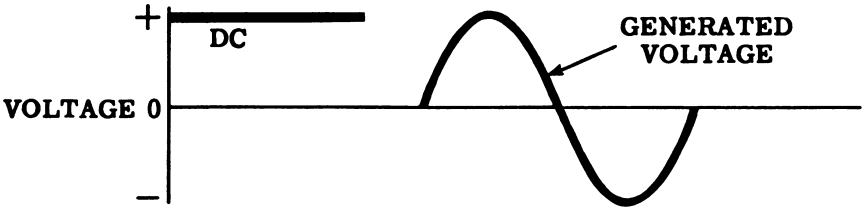
An elementary generator consists of a loop of wire placed so that it can be rotated in a stationary magnetic field to cause an induced current in the loop. Sliding contacts are used to connect the loop to an external circuit in order to use the induced emf.

The pole pieces are the north and south poles of the magnet which supplies the magnetic field. The loop of wire which rotates through the field is called the "armature." The ends of the armature loop are connected to rings called "slip rings," which rotate with the armature. Brushes ride up against the slip rings to pick up the electricity generated in the armature and carry it to the external circuit.

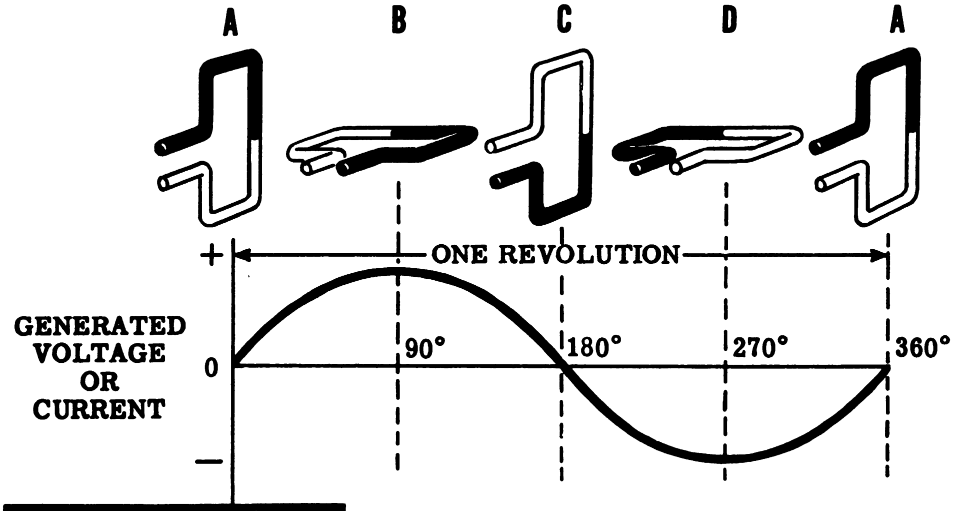


COMPARISON OF A-C TO D-C GENERATORS

Suppose you take a closer look at the output waveform of the elementary generator and study it for a moment. How does it compare to the voltages with which you have been dealing up to this time? The only voltages you have used so far are d-c voltages like those obtained from a battery. A d-c voltage can be represented as a straight line whose distance above the zero reference line depends upon its value. The diagram shows the d-c voltage next to the voltage waveform put out by the elementary a-c generator. You see that the generated waveform does not remain constant in value and direction, as does the d-c curve. In fact, the generated curve varies continuously in value and is as much negative as it is positive.



The generated voltage is, therefore, not d-c voltage, since a d-c voltage is defined as a voltage which maintains the same polarity output at all times. The generated voltage is called an "alternating voltage," since it alternates periodically from plus to minus. It is commonly referred to as an a-c voltage--the same type of voltage that you get from the a-c wall socket. The current that flows, since it varies as the voltage varies, must also be alternating. The current is also referred to as a-c current. A-C current is always associated with a-c voltage--an a-c voltage will always cause an a-c current to flow.



the AC waveform

You have seen how your elementary generator has generated a-c. Now, you might be wondering if the a-c generator can be modified to put out d-c rather than a-c. The answer is "yes."

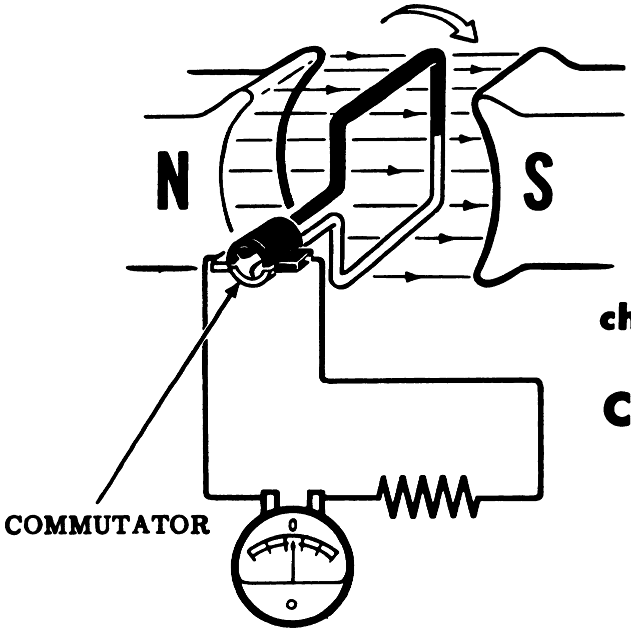
In the elementary generator, the a-c voltage induced in the loop reverses its polarity each time the loop goes through zero degrees and 180 degrees. At these points, the conductors of the loop reverse their direction through the magnetic field. You know the polarity of the induced emf depends on the direction a conductor moves through a magnetic field. If the direction reverses, the polarity of the induced emf reverses. Since the loop continues rotating through the field, the conductors of the loop will always have an alternating emf induced in them. Therefore, the only way that d-c can be obtained from the generator is to convert the generated a-c to d-c.

In order to convert the generated a-c voltage into a varying d-c voltage, the direction must be changed twice for every cycle. If the generator is putting out 60 cycles of a-c each second, the changes must occur 120 times per second to convert the a-c to d-c. It would be impossible to operate a switch manually at such a high speed.

The slip rings of the elementary generator can be changed so that they will accomplish this switching action. To do this, one slip ring is eliminated and the other is split along its axis. The ends of the coil are connected one to each of the segments of the slip ring. The segments of the split ring are insulated so that there is no electrical contact between segments, the shaft, or any other part of the armature. The entire split ring is known as the "commutator," and its action in converting the a-c into d-c is known as "commutation."

You see that the brushes are now positioned opposite each other, and the commutator segments are mounted so that they are short-circuited by the brushes as the loop passes through the zero voltage points. Notice also that as the loop rotates, each conductor will be connected by means of the commutator, first to the positive brush and then to the negative brush.

When the armature loop is rotated, the commutator automatically switches each end of the loop from one brush to the other each time the loop completes a half revolution.

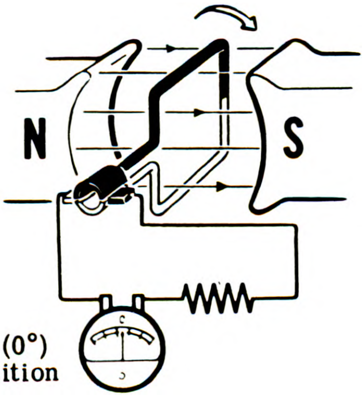


changing AC to DC using a COMMUTATOR

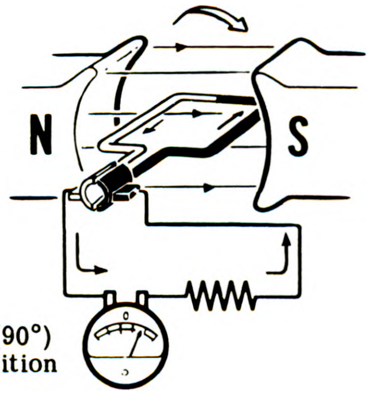
Converting a-c to d-c by use of the commutator: Suppose you analyze the action of the commutator in converting the generated a-c into d-c. In position A, the loop is perpendicular to the magnetic field, and there will be no emf generated in the conductors of the loop. As a result, there will be no current flow. Notice that the brushes are in contact with both segments of the commutator, effectively short-circuiting the loop. This short circuit does not create any problem since there is no current flow. The moment the loop moves slightly beyond position A (zero degrees), the short circuit no longer exists. The black brush is in contact with the black segment, while the white brush is in contact with the white segment.

As the loop rotates clockwise from position A to position B, the induced emf starts building up from zero until at position B (90 degrees) the induced emf is a maximum. Since the current varies with the induced emf, the current flow will also be a maximum at 90 degrees. As the loop continues rotating clockwise from position B to C, the induced emf decreases until at position C (180 degrees) it is zero once again.

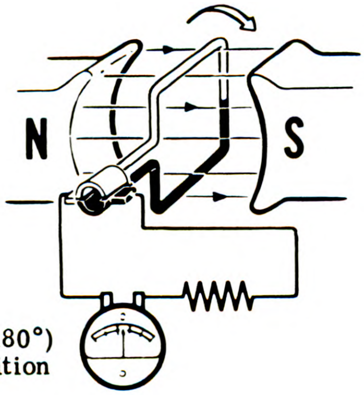
The waveform shows how the terminal voltage of the generator varies from zero to 180 degrees.



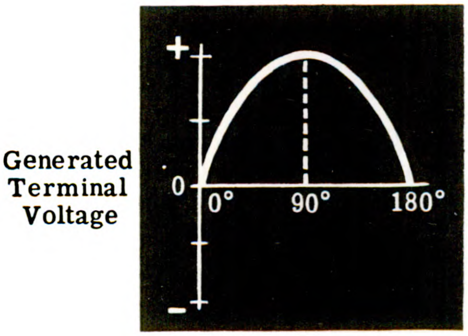
A (0°) position



B (90°) position



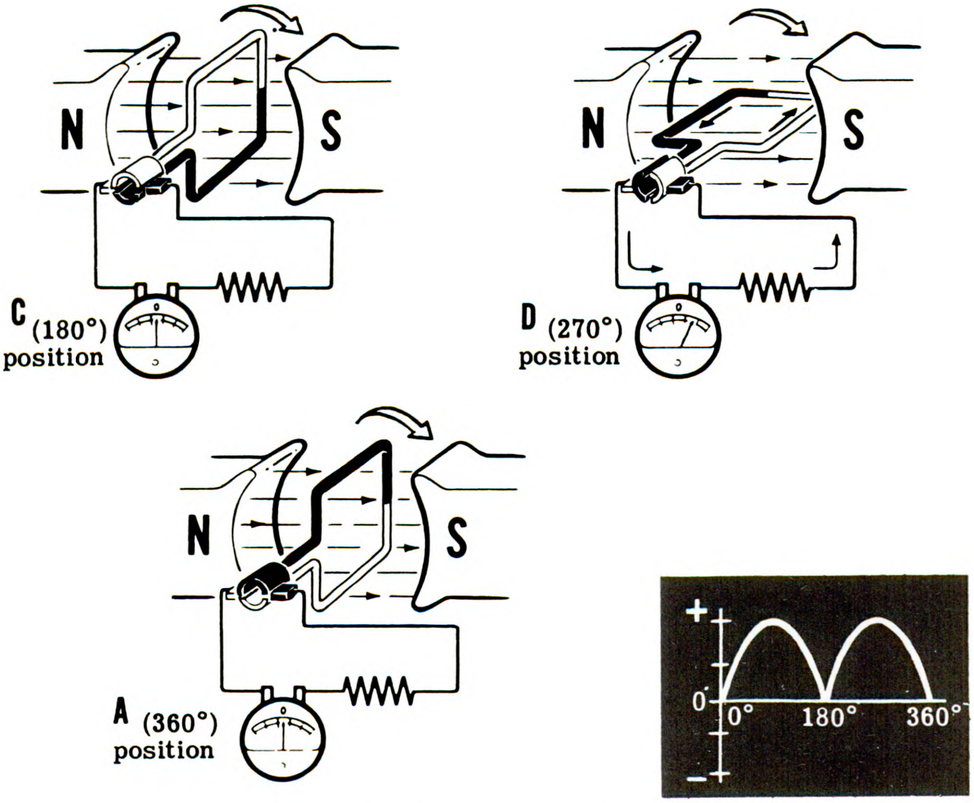
C (180°) position



Notice that in position C the black brush is slipping off the black segment and onto the white segment, while at the same time the white brush is slipping off the white segment and onto the black segment. In this way the black brush is always in contact with the conductor of the loop moving downward, and the white brush is always in contact with the conductor moving upward. Since the upward-moving conductor has a current flow toward the brush, the white brush is the negative terminal and the black brush is the positive terminal of the d-c generator.

As the loop continues rotating from position C (180 degrees) through position D (270 degrees) and back to position A (360 degrees or zero degrees), the black brush is connected to the white wire which is moving down, and the white brush is connected to the black wire which is moving up. As a result, the same polarity voltage waveform is generated across the brushes from 180 to 360 degrees as was generated from zero to 180 degrees. Notice that the current flows in the same direction through the current meter, even though it reverses in direction every half cycle in the loop itself.

The voltage output, then, has the same polarity at all times but varies in value, rising from zero to maximum, falling to zero, then rising to maximum and falling to zero again for each complete revolution of the armature loop.

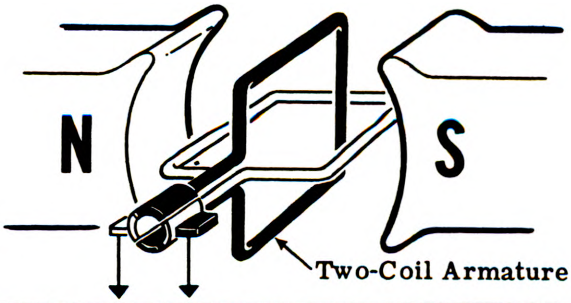


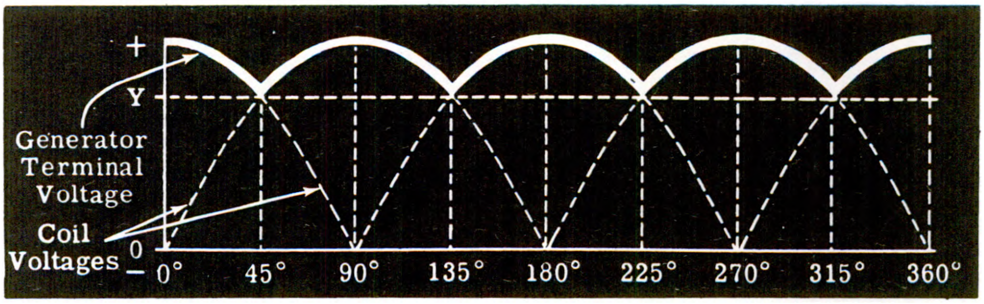
COMMUTATION-CONVERTING AC TO DC

Improving on the d-c output: Before you learned about generators, the only d-c voltage you were familiar with was the smooth and unvarying voltage produced, for example, by a battery. Now you find that the d-c output of an elementary d-c generator is very uneven--a pulsating d-c voltage varying periodically from zero to maximum. Although this pulsating voltage is d-c, it is not constant enough to operate d-c appliances and equipments. Therefore, the elementary d-c generator must be modified so that it will put out a smooth form of d-c. This is accomplished by adding more coils of wire to the armature.

The illustration shows a generator with a two-coil armature, with the two coils positioned at right angles to each other. Notice that the commutator is broken up into four segments, with opposite segments connected to the ends of a coil. In the position shown, the brushes connect to the white coil in which a maximum voltage is generated, since it is moving at right angles to the field. As the armature rotates clockwise, the output from the white coil starts dropping off. After an eighth of a revolution (45 degrees) the brushes slide over to the black commutator segments, whose coil is just beginning to cut into the field. The output voltage starts to pick up again, reaches a peak at 90 degrees and starts dropping off as the black coil cuts through fewer lines of force. At 135 degrees, commutation takes place once again and the brushes are again in contact with the white coil. The output voltage waveform for the entire revolution is shown superimposed on the single coil voltage. Notice that the output never drops below point Y. The rise and fall in voltage now is limited between Y and the maximum, rather than between zero and the maximum. This variation in the output voltage of a d-c generator is known as "generator ripple." It is apparent that the output of the two-coil armature is much closer to constant d-c than the output of the one-coil armature.

MANY COILS REDUCE GENERATOR RIPPLE





Even though the output of the two-coil generator is a lot closer to being constant d-c than the output of the one-coil generator, there is still too much ripple in the output to make it useful for electrical equipment. To make the output really smooth, the armature is made with a large number of coils, and the commutator is similiarly divided into a large number of segments. The coils are so arranged around the armature that at every instant there are some turns cutting through the magnetic field at right angles. As a result, the generator output contains very little ripple and is for all practical purposes a constant, or "pure," d-c.

SECTION VI

TOPIC 2

DIRECT-CURRENT GENERATORS

A. You have learned:	References:
1. How magnetism is put to use in a generator	
2. How basic generators are constructed	
3. How a-c and d-c generators differ	
B. You are learning:	
1. How D-C generators are constructed	NavPers 10622-B, pages 182 to 188
2. About self excited generators	NavPers 10170, pages 34 and 35; 40 and 41; 44 to 48)
3. About separately excited generators	NavPers 10170, pages 48 and 49
4. About commutation, self induction	NavPers 10170, pages 49 to 54
5. What armature reaction is and the effect of compensating windings	NavPers 10170, pages 54 to 56

CONSTRUCTION OF D-C GENERATORS

Name the major parts of the local power tachometer.

1. ______________________________ 2. ______________________________

3. ______________________________ 4. ______________________________

5. ______________________________

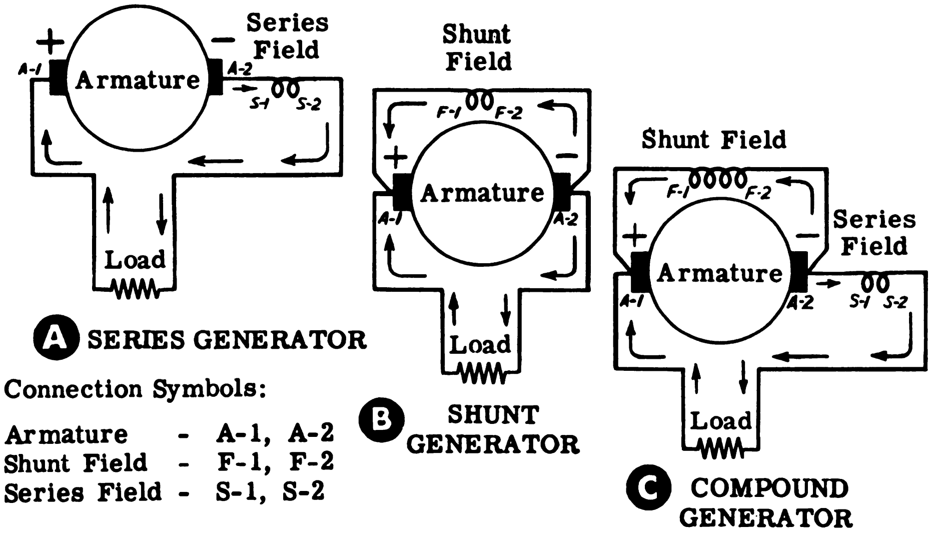
SELF-EXCITED D-C GENERATORS

Self-excited generators use part of the generator's output to supply excitation current to the field. These generators are classified according to the type of field connection used.

In a "series" generators, the field coils are connected in series with the armature, so that the whole armature current flows through both the field and the load. If the generator is not connected across a load, the circuit is incomplete and no current will flow to excite the field. The series field contains relatively few turns of wire.

"Shunt" generator field coils are connected across the armature circuit, forming a parallel or "shunt" circuit. Only a small part of the armature current flows through the field coils, the rest flowing through the load. Since the shunt field and the armature form a closed circuit independent of the load, the generator is excited even under "no load" conditions--with no load connected across the armature. The shunt field contains many turns of fine wire.

A "compound" generator has both a series and a shunt field, forming a series-parallel circuit. Two coils are mounted on each pole piece, one coil series- connected and the other shunt-connected. The shunt field coils are excited by only a part of the armature current, while the entire load current flows through the series field. Therefore, as the load current increases, the strength of the series field is increased.



SELF EXCITED D-C GENERATORS

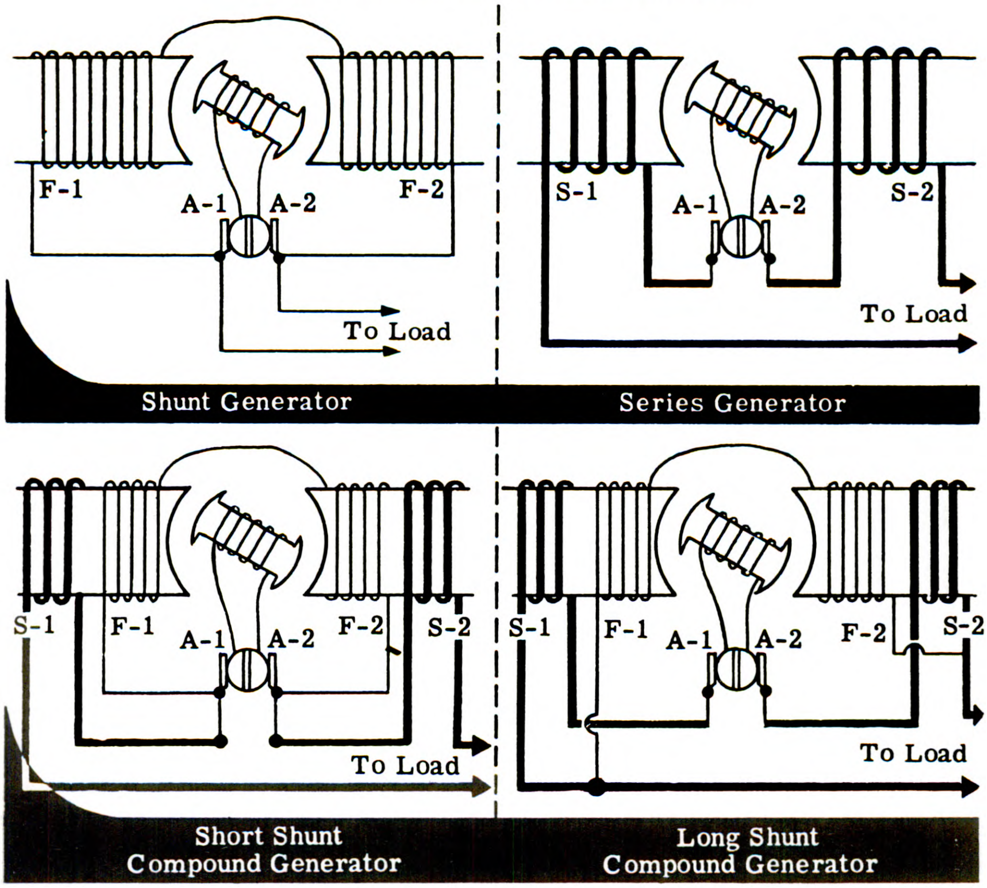
Shunt field coils, which connect directly across the generator output voltage, are constructed of many turns of small wire so that the coil resistance will be great enough to limit the current flow to a low value. Since the shunt field current is not used to supply the load, it is necessary to keep it to as low a value as possible.

If the shunt field of a compound generator is connected across both the series field and the armature, the field is called a "long shunt" field. If the shunt field is connected just across the armature, the field is called a "short shunt" field. The characteristics of both types of shunt connections are practically the same.

Series field coils are constructed of fewer turns of heavier wire and depend on the large current flow to the load resistance for their magnetic field strength. They must have a low resistance since they are in series with the load and act as a resistor to drop the voltage output of the generator. A comparison of the connections used for the various generator circuits is outlined as follows:

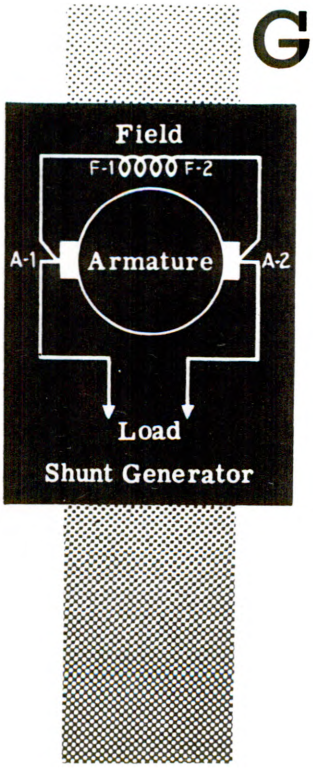
Almost all d-c generators used for lighting and power are the self-excited type, in which armature voltage is used to excite the field. However, if the original field excitation depends upon this armature voltage, and no voltage is induced in the armature coil unless it moves through a magnetic field, you may wonder how the generator output can build up. In other words, if there is no field to start with (since no current is flowing through the field), how can the generator produce an emf?

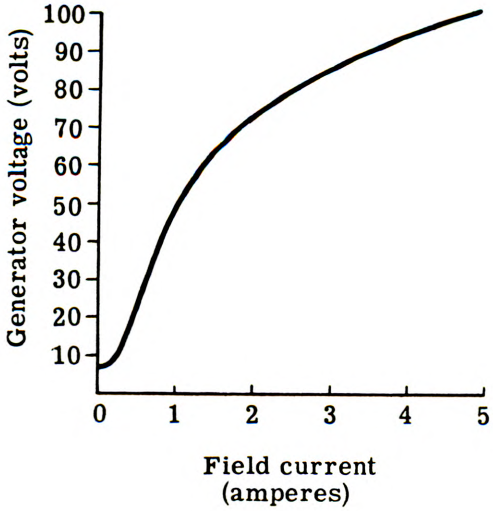
Actually, the field poles retain a certain amount of magnetism called the "residual magnetism," from a previous generator run, due to the magnetism characteristics of their steel structure. When the generator starts turning, an original field does exist which, although very weak, will still induce an emf in the armature. This induced emf forces current through the field coils, reinforcing the original magnetic field and strengthening the total magnetism. This increased flux in turn generates a greater emf which again increases the current through the field coils. This action increases until the machine attains its normal field strength. All self-excited generators build up in this manner. The build-up time normally is 20 to 30 seconds. The graph shows how generator voltage and field current build up in a shunt generator.



SELF-EXCITED GENERATOR FIELD CONNECTIONS

Generator Voltage *Build-up . . .*





Rember, the output of a generator is electrical power. A generator always has to be turned by some mechanical means--the prime mover. "Build-up" in a generator does not refer to its mechanical rotation; it refers to its electrical output.

Sometimes generators will not build up. When this happens, one of several things may be wrong.

There may be too little or no residual magnetism. To provide the initial field necessary, the generator must be excited by an external d-c source. This is called "flashing the field." When flashing the field, it is important to have the externally produced field of the same polarity as the residual magnetism. If these polarities are opposed, the initial field will be further weakened and the generator will still not build up.

The generator will not build up if the shunt field connections have been reversed. By reversing them again, the generator will build up properly.

Often a rheostat is connected in series with the shunt field, to control the field current. If this rheostat adds too much resistance to the circuit at first, the field current will be too small for a proper build-up.

Finally, if the field coil circuit has become "open," so that the circuit is not complete, the generator will not build up. The break, or open, must be found and repaired.

State four reasons why self-excited generators fail to build up.

1. ____________________

2. ____________________

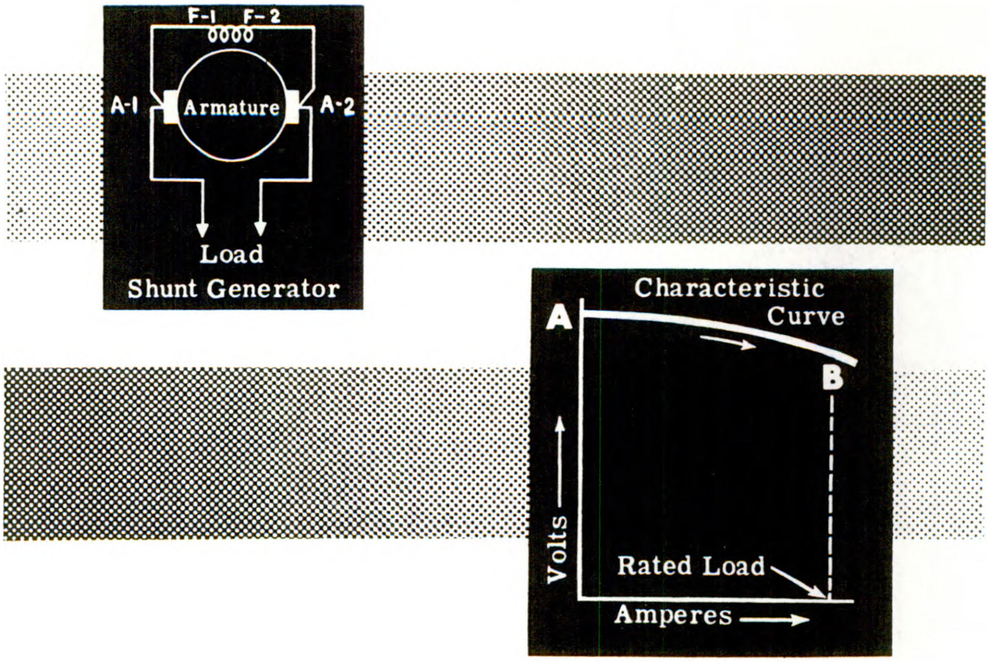
3. ____________________

4. ____________________

The Shunt Generator

The shunt generator has its field winding connected in shunt (or parallel) with the armature. Therefore, the current through the field coils is determined by the terminal voltage and the resistance of the field. The shunt field windings have a large number of turns, and therefore require a relatively small current to produce the necessary field flux.

When a shunt generator is started, the build-up time for rated terminal voltage at the brushes is very rapid since field current flows even though the external circuit is open. As the load draws more current from the armature, the terminal voltage decreases because the increased armature drop subtracts from the generated voltage. The illustration shows the schematic diagram and characteristic curve for the shunt generator. Observe that over the normal operating region of no-load to full-load (A-B), the drop in terminal voltage, as the load current increases, is relatively small. As a result, the shunt generator is used where a practically constant voltage is desired, regardless of load changes. If the load current drawn from the generator increases beyond point B, the terminal voltage starts dropping of sharply. The generator is never run beyond point B. The terminal voltage of a shunt generator can be controlled by varying the resistance of a rheostat in series with the field coils.



THE SHUNT GENERATOR

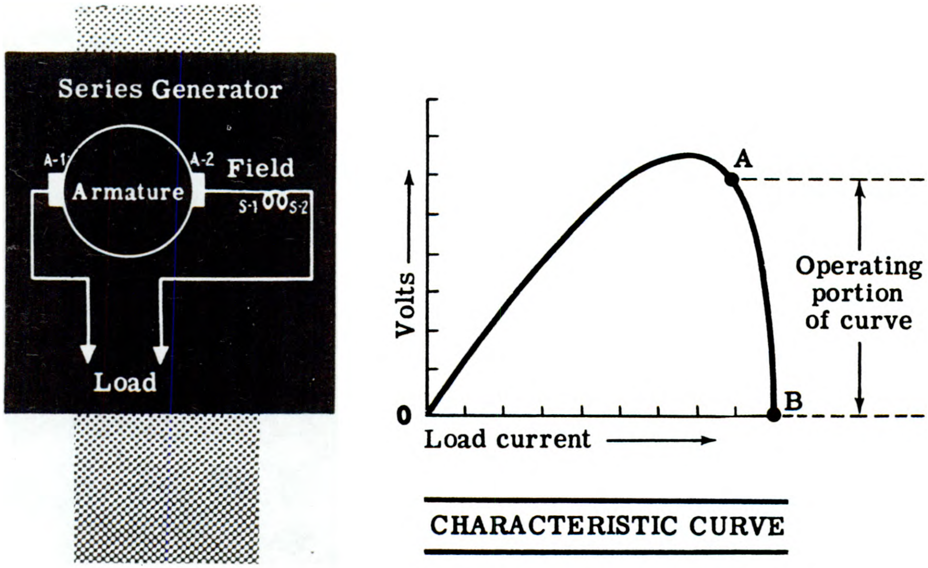
The Series Generator

In the series generator, the armature, the field coils, and the external circuit are all in series. This means that the same current which flows through the armature and external circuit also flows through the field coils. Since the field current, which is also the load current, is large, the required strength of magnetic flux is obtained with a relatively small number of turns in the field windings.

The illustration shows the schematic of a typical d-c series generator. With no laod, no current can flow and therefore very little emf will be induced in the armature--the amount depending upon the strength of the residual magnetism. If a load is connected, current will flow, the field strength will build up and, consequently, the terminal voltage will increase. As the load draws more current from the generator, this additional current increases the field strength, generating more voltage in the armature winding. A point is soon reached (A) where further increase in load current does not result in greater voltage, because the magnetic field has reached the saturation point.

Beyond point A, increasing the load current decreases voltage output due to the increasing voltage drop across the resistance of the field and armature. The series generator always is operated beyond this point of rapidly dropping terminal voltage (between A and B), so that the load current will remain nearly constant with changes in load resistance. This is illustrated by the voltage graph. For this reason, series generators are called "constant-current generators."

Series generators formerly were used as constant-current generators to operate arc lamps. At the present time, they are not used aboard ships in the Navy.

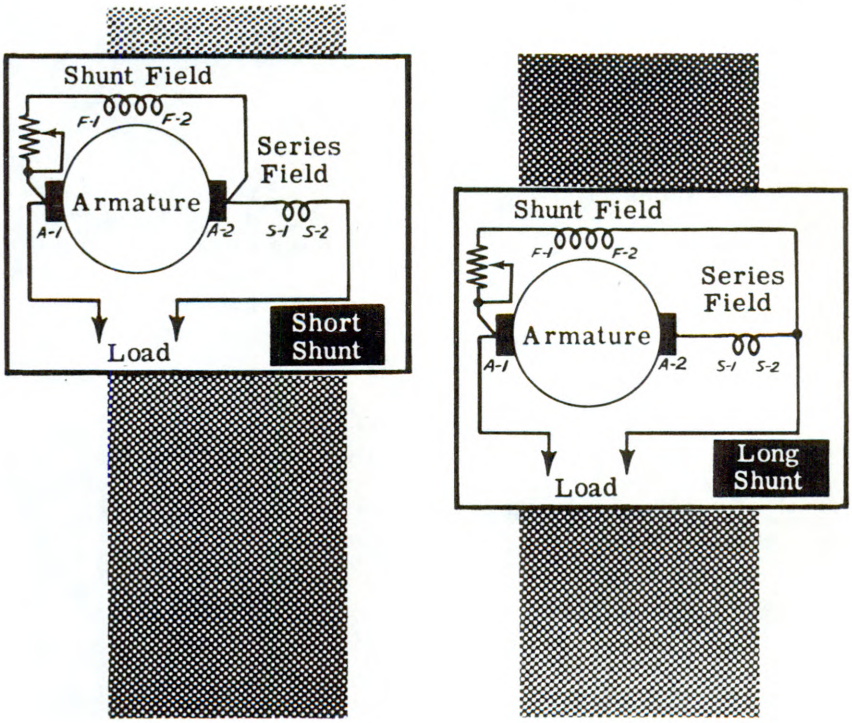


THE SERIES GENERATOR

The Compound Generator

A compound generator is a combined series and shunt generator. There are two sets of field coils--one in series with the armature and one in parallel with the armature. One shunt coil and one series coil are always mounted on a common pole piece, and sometimes enclosed in a common covering.

If the series field is connected so that its field aids the shunt field, the generator is called "cumulatively" compound. If the series field opposes the shunt field, the genera-



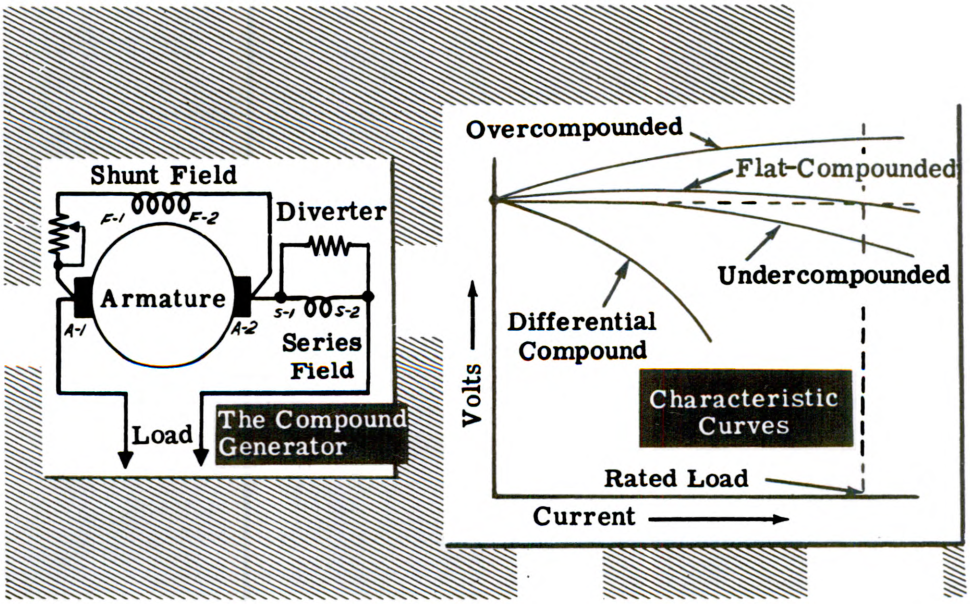
COMPOUND GENERATORS

tor is called "differentially" compound. Also, as explained before, the fields may be connected "short shunt" or "long shunt," depending on whether the shunt field is in parallel with both the series field and the armature, or just the armature. The operating characteristics for both types of shunt connections are practically the same.

Compound generators were designed to overcome the drop in terminal voltage which occurs in a shunt generator when the load is increased. This voltage drop is undesirable where constant-voltage loads, such as lighting systems, are used. By adding the series field, which increases the strength of the total magnetic field when the load current is increased, the voltage drop due to the added current flowing through the armature resistance is overcome, and constant voltage output is practically attained.

The voltage characteristics of the cumulative compound generator depend on the ratio of the turns in the shunt and series field windings. If the series windings are so proportioned that the terminal voltage is practically constant at all loads within its range, it is "flat-compounded." Usually in these machines the full-load voltage is the same as the no-load voltage, and the voltage at intermediate points is somewhat higher. Flat-compounded generators are used to provide a constant voltage to loads a short distance away from the generator. An "overcompounded" generator has its series turns so selected that the full-load voltage is greater than the no-load voltage. These generators are used where the load is some distance away. The increase in terminal voltage compensates for the drop in the long feeder lines, thus maintaining a constant voltage at the load. When the rated voltage is less than the no-load voltage, the machine is said to be "undercompounded." These generators are seldom used. Most cumulative compound generators are overcompounded. The degree of compounding is regulated by placing a low resistance shunt called a "diverter" across the series field terminal as shown. The terminal voltage can be controlled by varying the field rheostat in series with the shunt field. In a differentially compounded generator, the shunt and series fields are in opposition. Therefore the difference, or resultant field, becomes weaker and the terminal voltage drops very rapidly with increase in load current.

The characteristic curves for the four types of compound generators are illustrated.

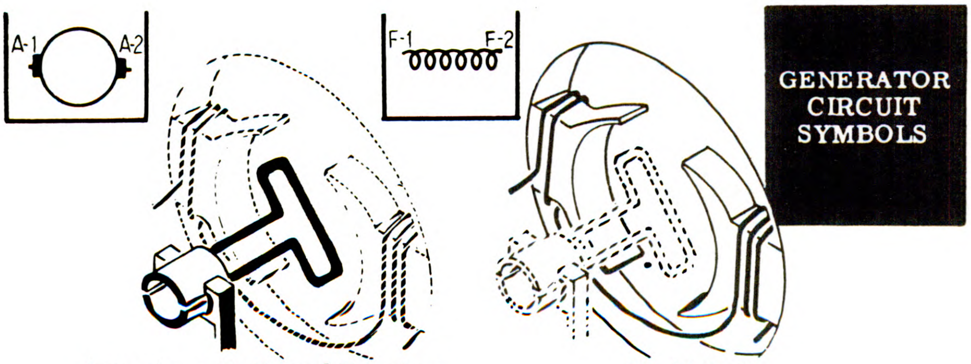


THE COMPOUND GENERATOR

SEPERATELY EXCITED D-C GENERATORS

Most practical d-c generators have electromagnetic fields. Permanentmagnet fields are used only in very small generators called "magnetos." To produce a constant field for use in a generator, the field coils must be connected across a d-c voltage source. (A-c current flow in a field coil does not produce a constant field and, therefore, an a-c voltage source cannot be used.) The d-c current in the field coils is called the "excitation current" and may be supplied from a separated d-c voltage source, or by utilizing the d-c output of the generator itself.

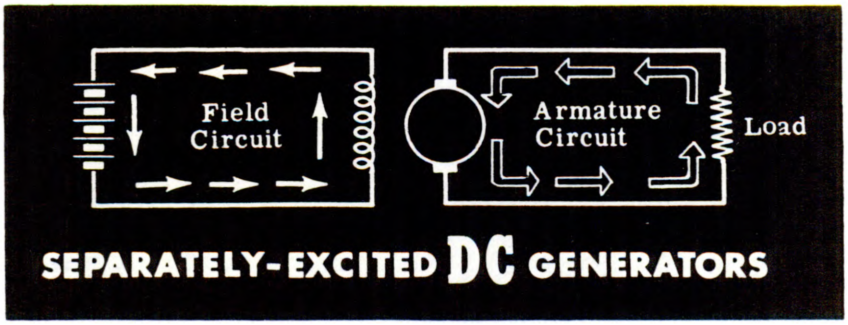
D-c generators are classified according to the manner in which the field is supplied with excitation current. If the field is supplied with current from an external source, the generator is said to be "seperately excited." However, if some of the generator output is used to supply the field current, it is said to be "self-excited." The circuit of the generator armature and field coils determines its type and affects its performance. Various generators utilize the three basic d-c circuits--series, parallel, and series-parallel. Symbols, as illustrated below, are used to represent the armature and field coils in the various generator circuits. The letters A, F, and S associated with motor and generator symbols refer to armature winding, shunt field winding, and series field winding, respectively.



Armature Coil and Brushes

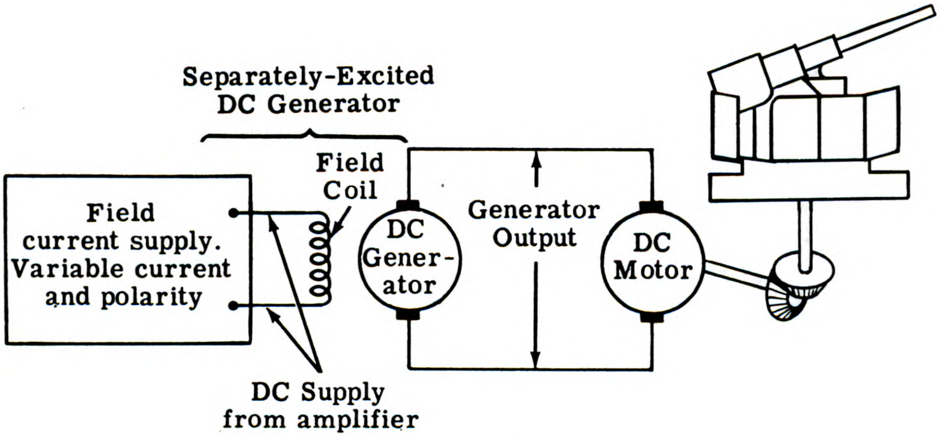
Field Coil

Separately excited d-c generators have two circuits, each entirely independent of the other--the field circuit consisting of the field coils connected across a separated d-c source, and the armature circuit consisting of the armature coil and the load resistance. (When two or more field coils are connected in series with one another, they are represented by a single symbol.) The two circuits of a separately excited generator are illustrated below, showing the current flow through the various parts of the circuit.



In a separately excited d-c generator, the field is independent of the armature, since, it is supplied with current from either another generator (exciter), an amplifier, or a storage battery. The separately excited field provides a very sensitive control of the power output of the generator, since the field current is independent of the load current. With a slight change in the field current, a large change in the load current will result.

The Navy uses separately excited generators mostly in automatic motor control systems. In these systems the field power is controlled by an amplifier, and the output of the generator supplies the armature current, which drives the motor. The motor is used to position a gun turret, gun mount, or any other heavy mechanism. Outside of these applications, the separately excited generator is seldom used in the Navy.



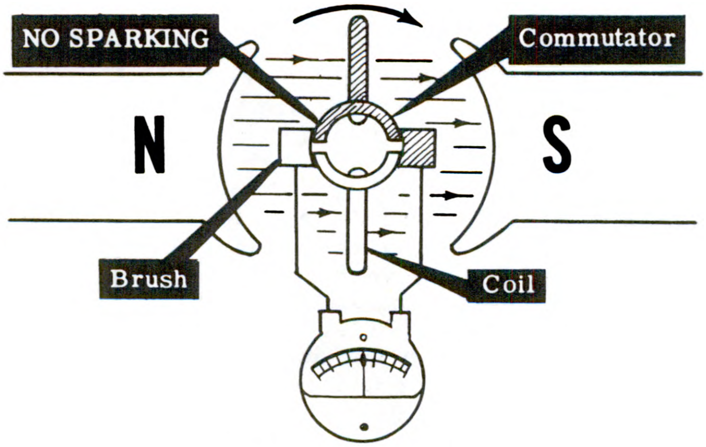
SEPARATELY-EXCITED D-C GENERATORS

What generators in the power drive correspond to the separately excited d-c generator in the above drawing?

COMMUTATION, SELF-INDUCTION, AND INTERPOLES

Commutation

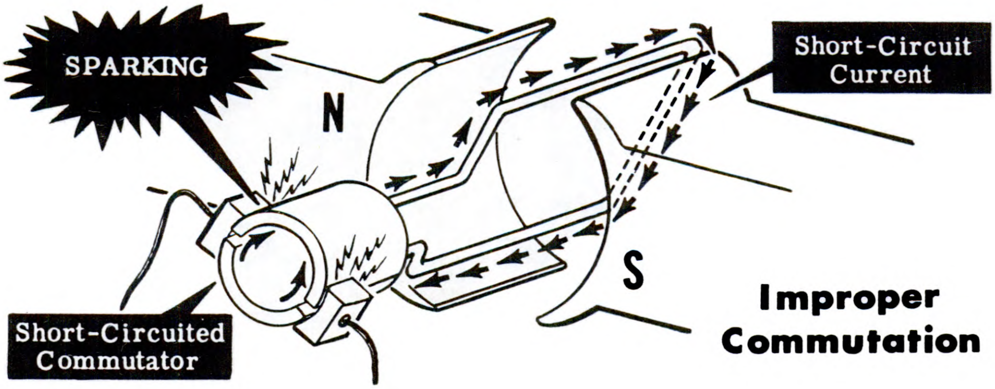
When you studied the elementary d-c generator, you learned that the brushes are positioned so that they short-circuit the armature coil when it is not cutting through the magnetic field. At this instant no current flows and there is no sparking at the brushes (which are in the act of slipping from one segment of the commutator to the next).



PROPER COMMUTATION

If the brushes are moved a few degrees, they short-circuit the coil when it is cutting through the field. As a result, a voltage will be induced in the short-circuited coil, and a short-circuit current will flow, and cause sparking at the brushes. This condition is undesirable since the short-circuit current may seriously damage the coils and burn the commutator. This situation can be remedied by rotating both brushes so that commutation takes place when the coil is moving at right angles to the field.

D-c generators operate efficiently when the plane of the coil is at right angles to the field at the instant the brushes short the coil. This plane which is at right angles to the field is known as the "plane of commutation" or "neutral plane." The brushes will short-circuit the coil when no current is flowing through it.



Improper Commutation

Emf of Self-Induction

You know that the armature conductors reverse their induced voltage as they pass through the neutral plane. As the voltage reverses, the current decreases to zero, then increases in the opposite direction.

This zero point is the exact place to commutate the coil. That is, this is the place to put the brushes--the neutral plane. Since commutation means shortening the coil with the brushes, the current must be zero at the instant of the short.

However, the picture is not as perfect as it looks. The flux field collapses around the conductor as the current falls to zero. You know the effect of that-an emf of self-induction is set up, and it tends to keep current flowing in the coil. Now the coil in the neutral plane should have zero current. But it doesn't. Due to the induced emf the coil in the neutral plane continues to carry current. And it does so even after it has passed through the neutral plane and started to cut flux of the next pole.

The net result of this is to shift the neutral plane in the direction of rotation, because the current does not go to zero until a short time after the coil passes the old neutral plane. This new neutral plane, where the coil's current is exactly zero, is called the "electrical neutral or commutating plane."

If the brushes are left at the old neutral plane, the commutation process is wrecked. Because, as the brush shorts the coil, a heavy current flows within the segments, coil, and brush. The commutator assembly overheats, and the sparks fly. The current jumps to the brush and each arc pits the commutator. Worse still, the arcs use up the generator's output voltage. That makes less voltage for the load. Sure, a sparking generator still operates--it can still deliver something to its load. But the delivered output is usually below the rated voltage. The commutator is very likely to be damaged, and the generator overheats.

State two unwanted effects of emf of self-induction.

1. ____________________

2. ____________________

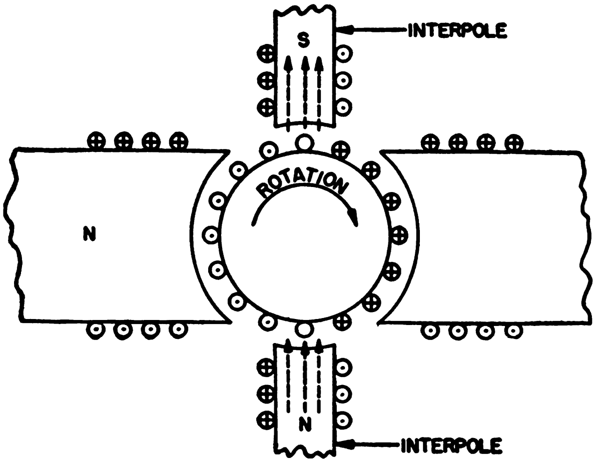
Interpoles

The interpoles overcome the emf of self-induction.

The process of reversing the current in the armature coils of a d-c generator is called commutation. The current stays the same until the coil reaches the zone of commutation and is placed on short circuit by the brush which spans at least two segments and more often three, or even four. In parallel-wound generator armatures, the two ends of a coil connect to adjacent commutator segments and when these segments come under a brush the coil is shorted. If the coil had no inductance and were moving parallel to the field, the current in the coil would come quickly to zero and build up in the opposite direction as the segments connected to it moved under the brush. The process would be effected without any sparking at the commutator.

Practically, there is an emf of self-induction generated in the coil by the collapsing field associated with the coil current decrease. This delays the decay of current so that by the time the segment moves out from under the brush, the current path is ruptured between the trailing edge of the segment and the toe of the brush, and an arc is formed. Bad sparking at the commutator limits the load on a generator.

Shifting the brushes forward will allow the coil being shorted to cut the field and generate an emf that overcomes the emf of self-induction, and sparking is reduced. When the load changes, the field shifts, and the brushes must be moved to a new position to avoid sparking at the commutator.



INTERPOLES IN A GENERATOR

With interpoles, the brushes are fixed on the no-load neutral at all times and good commutation is obtained for all loads automatically.

Interpoles set up a flux in the zone of commutation, which causes an emf to be generated in the coils being commutated, which overcomes the emf of self-induction. Notice that the interpole opposes the flux of the armature. It is a small pole and overcomes armature reaction only in the zone of commutation.

Getting back to the figure, you'll see that the interpole is about onethird the size of a main pole. And that it is located right in the neutral plane--where it can exert a maximum influence on the coils being commutated.

The problem of eliminating the emf of self-induction is to get the conductors into a flux field that will induce a voltage opposite to the emf of self-induction. Of course, they will get into that field later by passing under the next pole (which has opposite flux). But to get them into such a field soomer--soomer means nearer the neutral plane--put a small pole in the neutral plane that has the same polarity as the next main pole. Then the little pole will do the same job as the main pole, but sooner. The interpole is the little pole in the neutral plane. Notice that its polarity is the same as the next main pole in the direction of rotation. An interpole generator always has its brushes located on the no-load neutral plane. They are not shifted with load change.

You know that changes in the induced emf in the commutated coil are caused by changes in armature current. Therefore, connect the interpole in series with the armature. Then every time a change in armature current changes, the amount of induced emf the interpole likewise changes its strength. By having just the right number of turns on the interpole, it will have exactly the right strength to offset the different values of induced emf, and sparkless commutation is obtained for all loads.

It's a good system and it works. Just one thing--the polarity of the interpole is important. Remember, it must have the same polarity as the next main pole in the direction of rotation.

Explain briefly why interpoles are used.

ARMATURE REACTION AND COMPENSATING WINDINGS

Flux Distortion

Flux Distortion means exactly what it says--distorted or twisted flux. The following figure shows you how it happens. A is the straight field set up by the Field Poles of a generator. B is the somewhat circular field set up by the Armature. Perhaps you hadn't thought of a generator armature as setting up a field. You can bet that it does--any coil on an iron core carrying current sets up a magnetic field.

But the important diagram is C. This shows you what happens when the straight field of the poles reacts with the nearly circular field of the armature. Notice that the two fields are at an angle to each other, which means that the flux fields are going to combine to produce a resultant field that is distorted in the direction of rotation.

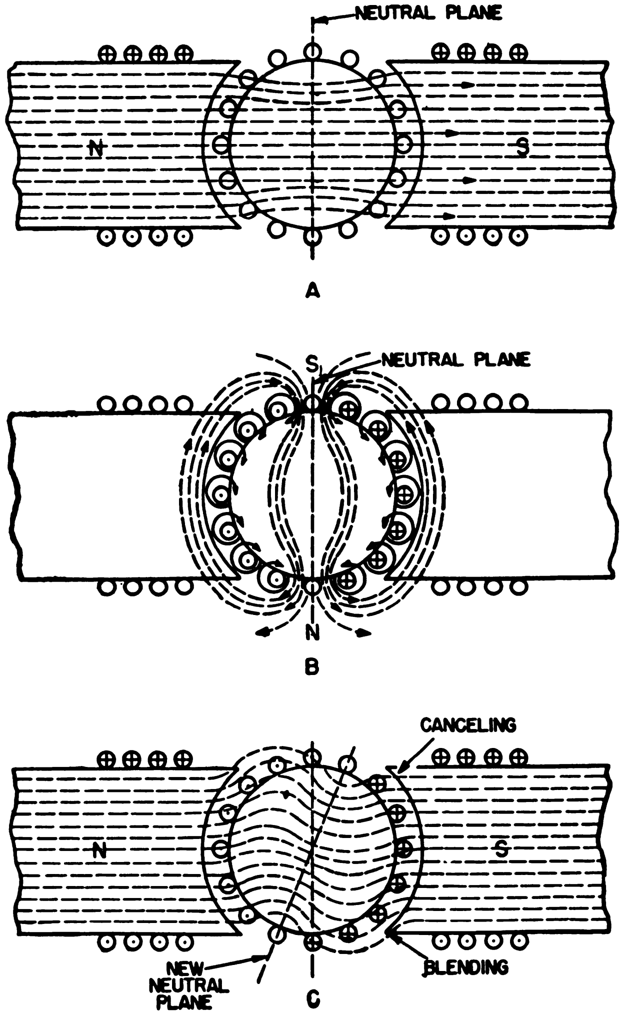
The blending occurs when the fields are nearly in the same direction. Result--an increase in the flux density in the poles.

The canceling occurs when the fields are nearly opposing each other. Result--a twisted flux and a decreased concentration of lines.

The total result is a distorted field and areas of unequal flux density. Be sure you see the twisting action. Be sure you locate areas of unequal density.

Go back to C of the figure and locate the new neutral plane. The new neutral plane, or the Commutating plane, is the plane where conductors cut no flux and carry no current. And that's where the brushes must be placed.

Now, put together the two factors which fouled up commutation. Emf of self-induction shifts the correct brush position in the direction of rotation. Likewise, flux distortion shifts the correct brush position in the direction of rotation. These two factors together are called Armature Reaction. They both tend to shift the neutral plane In The Direction Of Rotation.



FLUX DISTORTION IN A GENERATOR

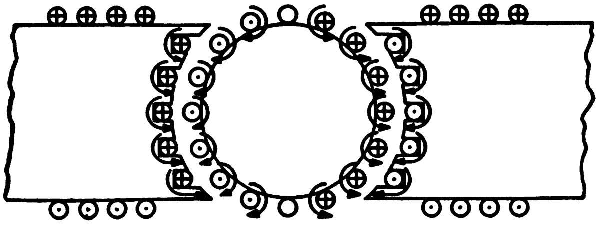
What to do about it?

Practically, you could shift the brushes to a position where they'd be in the commutating plane. The commutating plane is simple to find--simply adjust to the least sparking.

There's only one drawback to this method of correcting for armature reaction. It works only for a steady load. If the load changes, so does armature current. And that changes armature flux strength. Consequently, you'd have to shift the brushes for every change of load.

Compensating Windings

Compensating windings do the same job as interpoles but in a slightly different way. The following figure shows the compensating windings. Notice that the windings are embedded in the faces of the main poles, just across the air gap from the armature windings. And also notice that the current in the compensating windings is opposite to the current in the armature windings. Because the two currents are opposite, the compensating and armature fields are opposite. The armature field is practically canceled out. And with the armature field practically canceled, the armature reaction disappears.



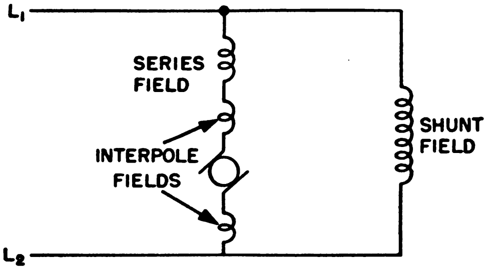
COMPENSATING WINDINGS IN A GENERATOR

Compensating windings, automatic?

Yes, because the compensating windings are connected in series with the armature just like the interpoles. They adjust to every change in armature current.

Sometimes, generators have both interpoles and compensating windings. When both are used, the effects of armature reaction are reduced to a minimum.

The following figure gives you a good review. It shows how either interpoles or compensating windings are connected in a compound generator. They're connected like a series field. But because of their position in the generator, they tend to eliminate the effects of armature reaction. And by eliminating the effects of armature reaction, arcing is cut down to a minimum. The commutator is saved from damage and the voltage output is kept at its rated value. The shunt field is never connected directly across the armature in an interpole generator. Armature current includes both load current and shunt field current and satisfactory commutation of this current depends on interpole field strength. The shunt field connection is always the armature and interpole field in series to insure interpole flux in proportion to total armature current.



INTERPOLE OR COMPENSATING WINDING CONNECTION

How are compensating windings energized? ____________________

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Why are compensating windings used in a d-c generator? ____________________

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SECTION VI

TOPIC 3

DIRECT CURRENT MOTORS

A. You have learned:	References:
1. Basic generator principles	
2. Construction, types, uses, and principles of d-c generators	
B. You are learning:	
1. The uses and operation of d-c motors	NavPers 10170, pages 57 and 58 NavPers 10622-B, pages 193 and 194
2. The principle of motor action	NavPers 10622-B, pages 195 to 211
3. The classes of d-c motors, especially the type used in the power drive	NavPers 10170, pages 58 to 63
4. About motor control	NavPers 10170, pages 63 to 69 NavPers 10622-B, pages 211 to 216
5. Power drive d-c machinery maintenance	NavPers 10170, pages 71 to 83

INTRODUCTION TO MOTORS

Direct current motors are used in the power drive to drive the mount in train and elevation. The d-c drive motor converts electrical energy received from a d-c generator to mechanical energy to move the mount in train or elevation.

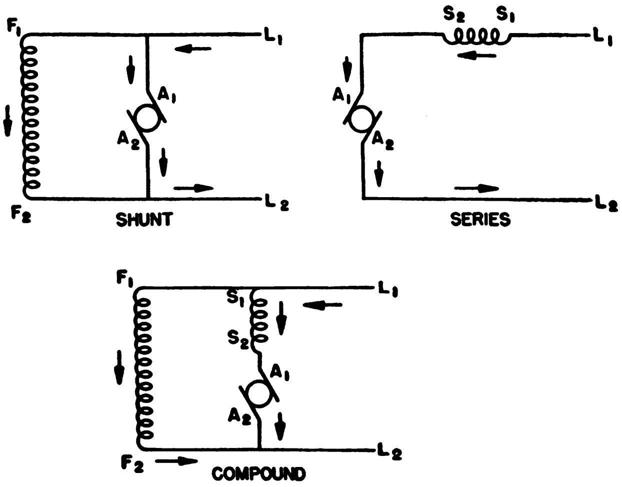
Motors are built just like generators. Motors are also connected just like generators--there's a shunt, a series, and a compound connection. The types of connection have two purposes, just as in generators--to excite the field and to produce different operating characteristics under load.

Just refresh your memory. The following figure shows all the connections for motors. Look it over, you'll find they're the same as for generators. But there's one thing to remember--motors take power from the line.

You were interested in two things about generators--the load current and the voltage. Because that's what a generator produces. Current and voltage are the electrical power output of a generator.

But, you study the speed and torque of motors. Because that's what a motor produces. Speed and torque are the mechanical power of a motor.

Speed and torque depend on the reaction of two fields of flux--the armature field and the field of the pole pieces. Since both of these fields are produced by current flowing in electromagnets, the strength of the fields is proportional to the current in their windings.



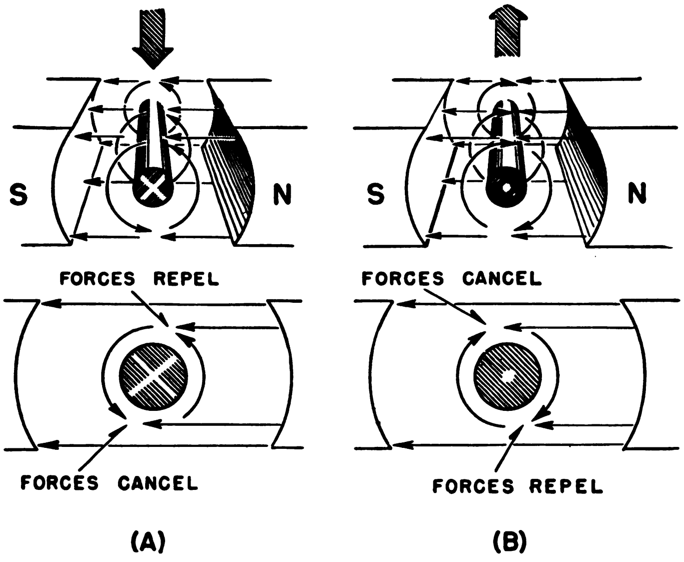
MOTOR CONNECTIONS

MOTOR ACTION

A current-carrying conductor in a magnetic field exerts a force against the field. The force tends to push the conductor out of the field. This is the principle of operation of the d-c motor.

The magnetic field is furnished by the field coils, pole pieces, and frame. As in the generator, the field is stationary and steady. Current is sent into the armature windings and sets up a magnetic field around the armature. The two fields--armature and field coils--react against each other. The result is a force against the armature windings which tends to push them out of the field. Since these windings are fastened to the armature core and shaft, they tend to move out of the field also.

The figure summarizes motor action. The direction of push reverses when the current is reversed. The direction of push also reverses when the pole pieces change polarity.



MOTOR ACTION

Notice in the A drawings that the flux above the conductor blends with the flux of the field.

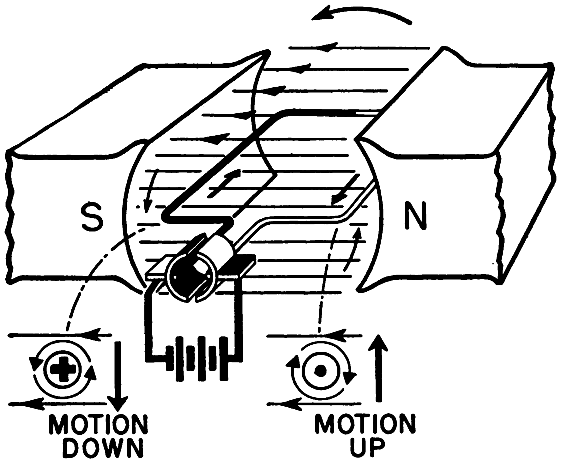
The flux below the conductor cancels the field flux. This results in a strong but distorted field above and a weak field below. The conductor moves downward into the weakest area. In B, the current is reversed--the field below is strong and distorted, and the field above is weak. The conductor moves upward.

Evidently, motor action is the result of two magnetic fields reacting on each other. It's a lot like two south or two north poles repelling each other--if one of the poles is free to move, a simple motor action is produced.

The simplest motor would be a wire in a magnetic field with a mechanical load attached. Every time the circuit was closed, the wire would move, dragging its load with it. When the circuit was reversed, the wire would reverse and push its load back again. This kind of a motor is impractical. In the first place, it's too weak to do much work. And in the second place, straight-line, back and forth motion is inefficient and slow.

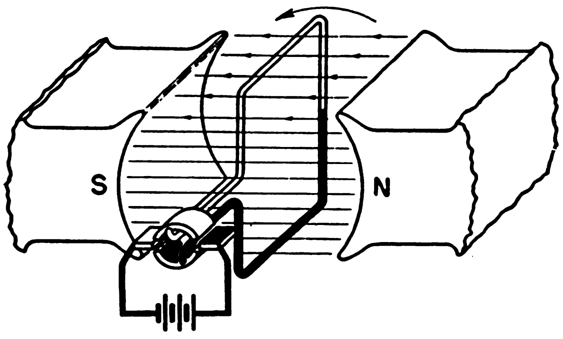
To increase the strength, add more conductors so that the forces add. To eliminate the straight-line motion, make the set of inductors rotate. Here's how it's done. A single-turn coil is mounted in a magnetic field as in figure 1. Note that the current direction is traced by arrows. The left-hand side of the coil is carrying current in. And this side moves downward. The right-hand side of the coil carries current out. And the motion is upward. The small drawings, just below each coil side, shows what happens to the flux at each side. Now, if the right side moves up, the left side moves down and the coil is pivoted along its center line, and counterclockwise rotation is produced.

The forces against these conductors are straight-line forces, but, because the coil is pivoted, they can't move in a straight line. They are obliged to move in a curve--a part of a circle. When a force produces a circular or twisting motion, the result is called a torque.

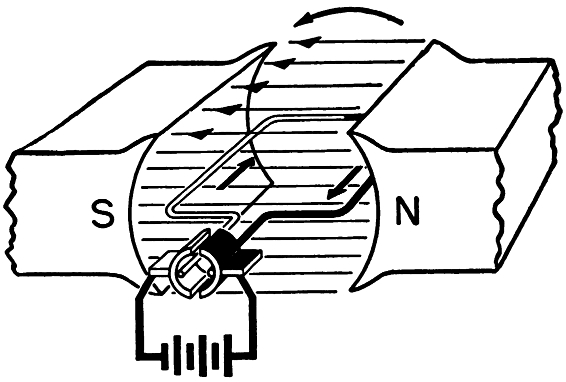


ONE LOOP MOTOR ACTION--1

The torque on this loop continues until it is in the position shown in figure 2. The coil is in the neutral plane--no torque is produced. The segments on the commutator are breaking contact with their brushes. Current is about to reverse direction in each coil side by switching brush connections. Even if the brushes were not breaking contact, the torque would be zero, because the upward and downward forces cannot produce rotation from this position. The forces are alined with the pivoting shaft. No twist--no torque. Will the coil stop on the neutral plane? Only if it is turning very slowly. Usually, the momentum is great enough to carry the coil through the neutral plane. Just past the neutral plane the segments switch brushes. This reverses the coil current.



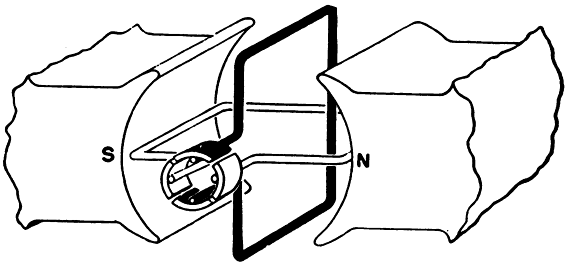
ONE LOOP MOTOR ACTION--2



ONE LOOP MOTOR ACTION--3

Examine figure 3. The white side of the coil is now forced downward and the black side upward. This keeps the coil rotating in a counterclockwise direction. The total effect of all the forces operating on the coil has been to produce a torque in a counterclockwise direction.

One coil turning in a field is a motor all right, but the load it is capable of driving is EXTREMELY small. Furthermore, every time the coil passes through the neutral plane, the torque is zero. This zero point introduces a jerk to the rotation. All you have to do to make the motor stronger and to eliminate the zero torque points, is simply add another coil at right angles to the first.



TWO LOOP MOTOR ACTION--4

Look at figure 4. With the two coils arranged like this, only the coil in the best position to produce torque is connected to the brushes. The power is doubled and the points of zero torque are eliminated.

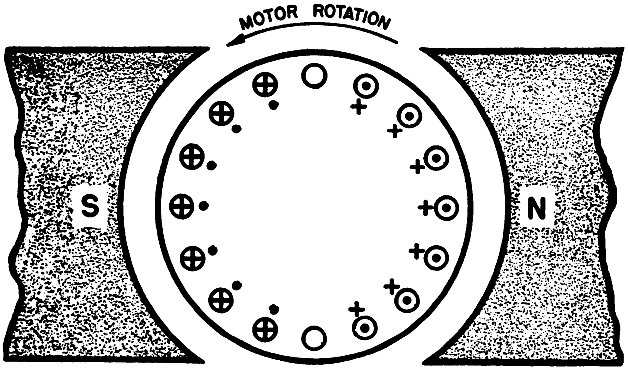
Motors would burn up if a cemf weren't induced in their armature windings.

The fields set up around the conductors on the armature react with the fields set up by the pole pieces. Torque is produced and motor rotates counterclockwise.

As the armature rotates, ITS CONDUCTORS CUT THROUGH THE FIELD FLUX. A voltage is induced in these conductors. This generated voltage is opposite to the voltage applied at the brushes. The figure shows the direction of the applied voltage and the direction of the generated voltage. The generated and applied voltages in a motor are ALWAYS OPPOSITE.

The generated voltage in a motor is called "counter-electromotive force."

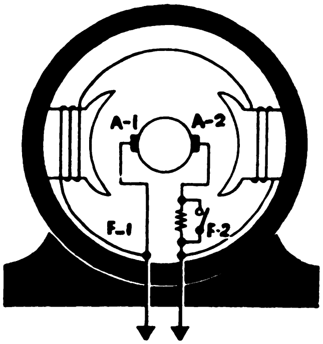
This means that there are two voltages operating on every conductor on the armature of a motor. Moreover, these two voltages are opposing each other. Current, then, is a result of a combination of two voltages. The COUNTER-EMF IS ALWAYS LESS THAN THE APPLIED EMF.



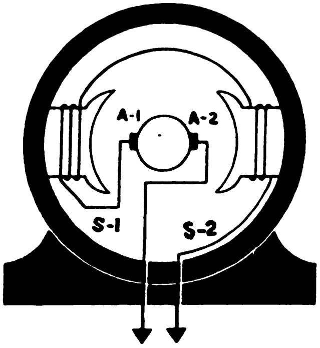
DIRECTION OF COUNTER-EMF

CLASSES OF MOTORS

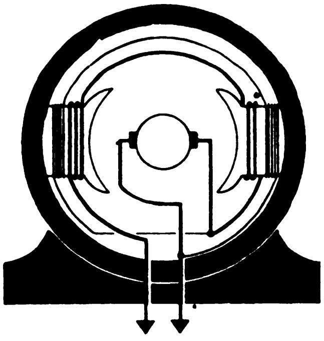
Motors, like generators, are classed by their type of winding and the type of excitation.



Shunt Motors--The field windings are connected in parallel across the armature coil and the field strength is independent of the armature current. Shunt motor speed varies only slightly with changes in load, and the starting torque is less than that of other types of d-c motors.

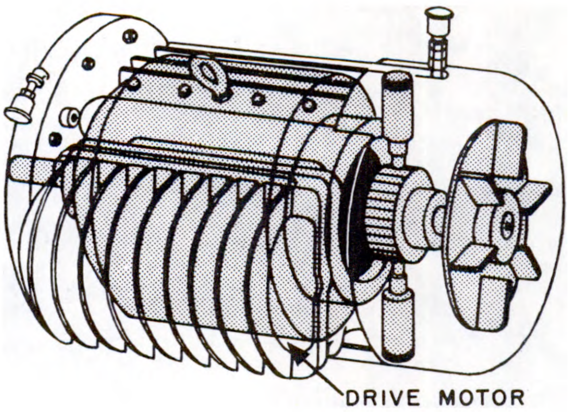


Series Motors--The field windings are connected in series with the armature coil and the field strength varies with changes in armature current. When its speed is reduced by a load, the series motor develops greater torque, and its starting torque is greater than that of other types of d-c motors.



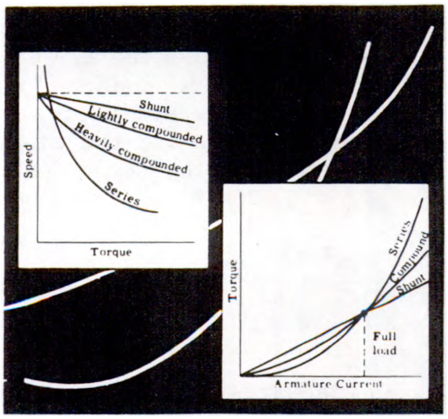
Compound Motors--One set of field windings is connected in series with the armature, and one set is parallel-connected. The speed and load characteristics can be changed by connecting the two sets of fields to either aid or oppose each other.

Drive Motors--The two drive motors of the power drives are direct-current motors of conventional design. Like the d-c generator, they have an armature and a magnetic field. The magnetic field in this case is provided by permanent magnets built into the motor. The current generated by the amplidyne is connected to the brushes, and flows through the armature. The magnetic poles created in the armature by this current are attracted or repelled by the permanent magnets, causing the motor to rotate. The speed of rotation depends on the strength of the current; direction, on the current polarity. A small series winding is placed at right angles to the main magnetic field. Its purpose is to prevent demagnetization of the tips of the permanent magnets.



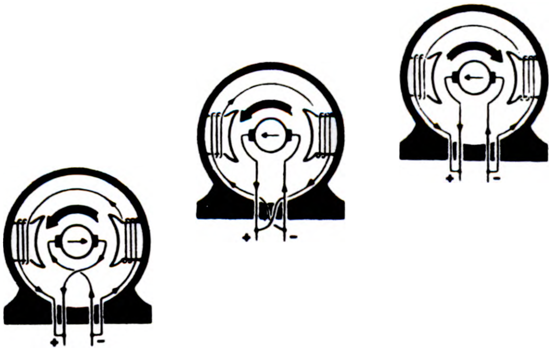
Actually, the drive motors are permanent-magnet, separately excited d-c motors with interpoles and compensating windings.

D-C Motor Characteristics--D-c shunt, series, and compound motor circuit connections are the same as those of the corresponding type of d-c generator. Speed and torque versus armature current are used as comparison characteristics for d-c motors.

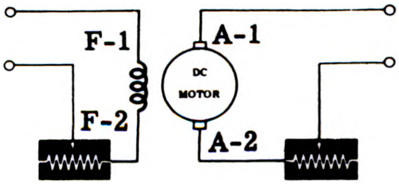


MOTOR CONTROL

Motor Reversal--The direction of rotation of a d-c motor can be reversed by reversing the field connections or by reversing the armature connections.



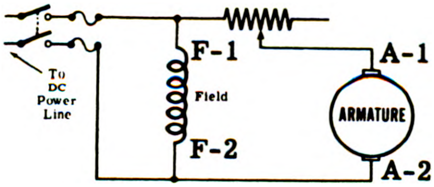
D-C Motor Speed Controls--The speed of a d-c motor can be varied with a variable resistance connected either in series with the field coil or in series with the armature coil. Increasing shunt field circuit resistance increases motor speed, while increasing the armature circuit resistance decreases motor speed.



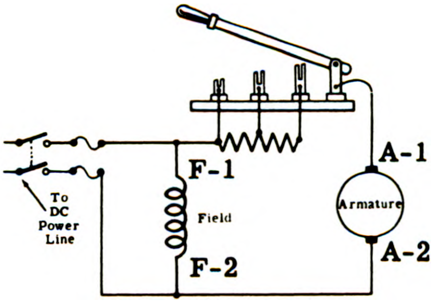
To summarize, the speed of rotation of a d-c motor depends on the field strength and the armature voltage.

D-C MOTOR STARTERS

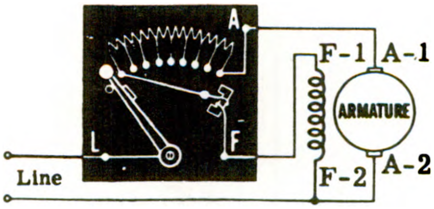
D-C Starter--A device to limit the starting current of a motor. A resistance, connected in series with the armature, are progressively removed from the circuit. Elementary starters may be operated manually or used with a holding coil.



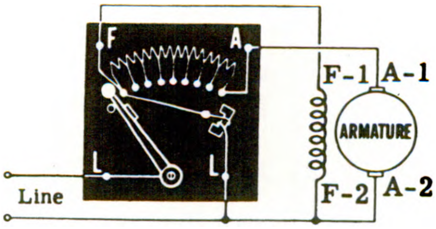
Elementary Starter--A starter assembly in which sections of a resistance, connected in series with the armature, are progressively removed from the circuit. Elementary starters may be operated manually or used with a holding coil.



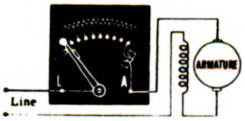
Three-Point Starter--A starter assembly having three connections--line, armature, and field--to connect a starting resistance in series with the armature and a holding coil in series with the shunt field. As the starter arm is moved across the resistance tops, the starter resistance is removed from the armature circuit. With the starter in the ON position, the holding coil holds the starter arm there until the applied voltage is reduced or removed.

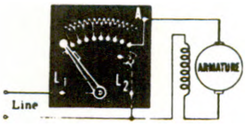


Four-Point Starter--A starter assembly similar to the three-point starter except that the holding coil connects directly across the power line, rather than in series with the shunt field winding. Four-point starters are used when a variable resistance is connected in the field circuit as a speed control.



Series Motor Starters--Two-point series motor starters use a high-current holding coil connected in series with the motor leads, while three-point starters use a low-current holding coil connected across the power line.





D-C MACHINERY MAINTENANCE

Motors and generators may use either sleeve or ball bearings to reduce friction and must be properly lubricated. Some bearings have permanent lubrication. All other lubrication must be performed according to lubrication instructions for that type of equipment.

Next to bearings, commutators and brush assemblies are the chief sources of trouble in d-c rotating machinery. Worn brushes and commutators cause excessive arcing which aggravates the trouble. Brush spring tension maladjustment is another common casualty.

Breakdown of insulation may be caused by oil, salt water, and dirt. This casualty can usually be checked with a megger ground test.

Open windings are easily detected with an ohmmeter. Shorted windings will read zero on the low ohmmeter scale but partial shorts will indicate a fraction of the specified resistance.

JOB SHEET NO. 25

1. Motors take their power from the ______________________________.

2. Speed and torque depend on the reaction of the ______________________ field and the field of the ______________________.

3. What two quantities determine the direction of rotation of a motor?

   a. ____

   b. ____

4. What effect does cemf have on armature current?

   a. ____

5. What happens to the amount of cemf if the motor is slowed down?

   a. ____

6. What effect does decreased cemf have on the amount of current?

   a. ____

7. What is the principle function of a starter?

   a. ____

8. What are the two methods of reversing a motor?

   a. ____

   b. ____

9. An ______________________ is used to check a motor for open windings.

SECTION VI

TOPIC 4

TRANSFORMERS

A. You have learned:	References:
1. That a-c causes an expanding and collapsing field	
2. About self-induction	
3. About mutual induction	
4. That lines of force travel through iron more easily than through air	
B. You are learning:	
1. Where transformers are used.	NavPers-10622-B, pages 311 and 312
2. How transformers work	NavPers-10622-B, pages 312 to 314
3. About voltage, current, turns, and power rates	NavPers-10622-B, pages 314 to 320 and 327 to 329
4. About transformer construction	NavPers-10622-B, pages 320 to 326
5. The transformer types	
6. Transformer maintenance	
C. You will develop skill in:	
1. Tracing circuits	
2. Reading meters	

WHAT IT IS AND ITS USES

Transformers are a-c machines that step up or step down voltage. Because they have no moving parts, there is no mechanical wear, which gives excellent efficiency and calls for very little maintenance.

TRANSFORMERS DO NOT INCREASE OR DECREASE POWER because an increase in voltage through a transformer causes a decrease in current, and a decrease in voltage causes an increase in current.

State six uses for transformers in the elevation power drive.

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

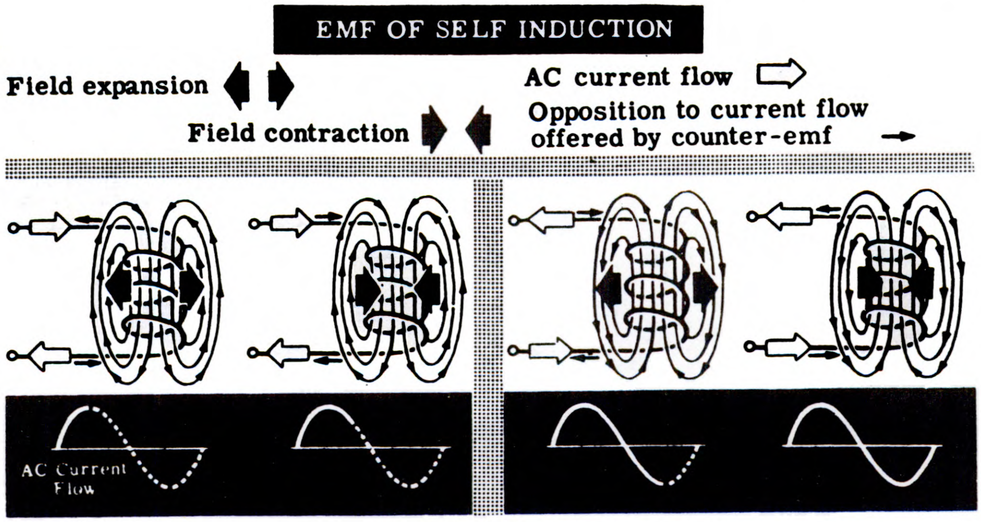
6. ____________________

What is the transformer in the air supply unit used for? ______________________________

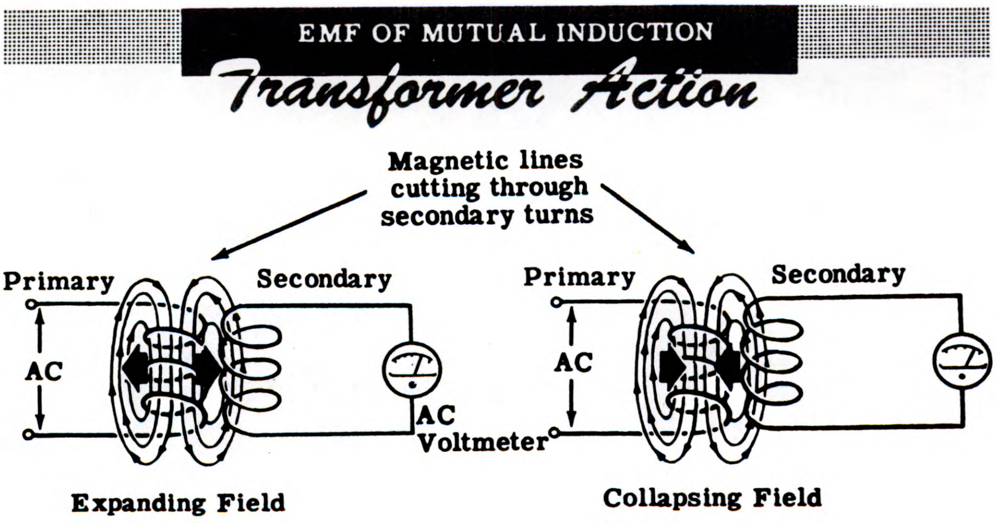
____

HOW A TRANSFORMER WORKS

When a-c flows through a coil, an alternating magnetic field is generated around the coil. This alternating magnetic field expands outward from the center of the coil and collapses into the coil as the a-c through the coil varies from zero to a maximum and back to zero again. Since the alternating magnetic field must cut through the turns of the coil, an emf of self-induction is induced in the coil, which opposes the change in current flow.


EMF OF SELF INDUCTION

If the alternating magnetic field generated by one coil cuts through the turns of a second coil, an emf will be generated in this second coil just as an emf is induced in a coil which is cut by its own magnetic field. The emf generated in the second coil is called the "emf of mutual induction," and the action of generating this voltage is called "transformer action." In transformer action, electrical energy is transferred from one coil (the primary) to another (the secondary) by means of a varying magnetic field.


EMF OF MUTUAL INDUCTION

Transformer Action

With no load, what limits current in the primary? ______________________________

____

Explain how an increase in secondary current causes an increase in primary current.

____

____

____

Transformers are as high as __________% efficient.

Power loss due to the resistance of the windings is called ______________________

______________________.

Core losses are due to ______________________________ and ____________________.

Why are some transformer cores laminated? ______________________________

____

E, I, T, AND P RATIOS

Sketch a simple transformer schematic and apply the following values:

Primary voltage equals 115 volts.
Primary has 345 turns.
Turns ratio is one to four.
Secondary has ____ turns.
Secondary voltage equals ______ volts.
Is this transformer step-up or step-down?

____

The voltage induced in the secondary depends upon the ________________________ between the secondary and primary.

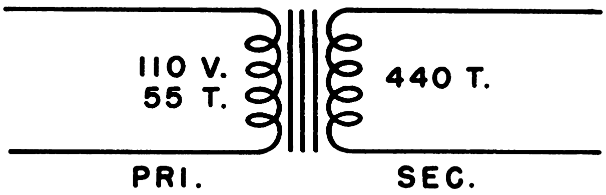
The no-load current in the primary is called the ______________ current.

How many turns per volt in this secondary? ______________.

How many volts across this secondary? ______________________.

Secondary current is determined by the ______________________________.

Primary current depends on secondary ______________________________.



Ampere turns (IT) of the primary are equal to the ampere turns of the secondary.

The frequency of the output depends on the frequency ______________________________

______________________.

The polarity of the secondary is usually ______________________________ the polarity of the primary.

What is the best way to reverse the polarity of transformer output? ______________

____

TRANSFORMER CONSTRUCTION

List the three major parts of a transformer. 1. ______________

2. ______________ 3. ______________

Why can't laminated silicon steel cores be used in high-frequency transformers?

____

____

What type core is the most efficient? ______________. Why? ______________

____

State three ways in which transformers may be cooled. 1. ______________

______________ 2. ______________ 3. ______________

What are the two most common types of windings? 1. ______________

2. ______________. Which is the easiest to repair? ______________

______________. Which type is employed in the transformers of the power drive.

TYPES OF TRANSFORMERS

With the use of figure 103, OP 821 A, determine which transformers are used for:

1. Plate supply
2. Filament supply
3. Bias supply
4. Signal transformers

Explain very briefly what is meant by an audio transformer. ______________

____

____

How many winding are there in an autotransformer? ______________

TRANSFORMER TROUBLESHOOTING

What two types of meters can be used when checking for an open winding?

1. ______________ 2. ______________

Overheating is an effect of a shorted or partially shorted transformer. A partial short in the secondary will cause a ______________ voltmeter reading. What will be the voltmeter reading across the secondary if the primary is completely shorted?

When checking for insulation breakdown, a ______________ should be used.

SECTION VI

TOPIC 5

ALTERNATING CURRENT MOTORS

A. You have learned:	References:
1. What a-c is	
2. About d-c motors	
3. About self-induction and mutual-induction	
4. That like poles repel and unlike poles attract	
B. You are learning:	
1. About the different types of motors used in the power drive	NavPers 10622-B, pages 217 to 235
2. Theory and operation of the three-phase induction motor	NavPers 10622-B, pages 224 to 229; & 231
3. Theory and operation of the split-phase induction motor	OP 1040, pages 342 to 347

TYPES OF A-C MOTORS

A-c motors furnish mechanical power on nearly all types of ships in the Navy. A-c motors can, in most cases, duplicate the operation of d-c motors and are less troublesome to keep in peak operating condition. This is because d-c motors encounter difficulties due to the action of commutation which involve brushes, brush holders, neutral planes, etc. Many a-c motors do not even use slip rings, with the result that they give trouble-free operation over long periods of time.

A-c motors are particularly well suited for constant-speed applications, since the speed is determined by the frequency of the a-c applied to the motor terminals.

A-c motors may operate from a single-phase, or multiphase a-c line. The principle of operation is that the a-c applied to the motor generates a rotating magnetic field, and it is this rotating magnetic field that causes the rotor of the motor to turn.

A-c motors are generally classified into two types:

1. The synchronous motor is an alternator operated as a motor, in which three-phase a-c is applied to the stator and d-c is applied to the rotor.

2. The induction motor does not have its rotor connected to any source of power and is the type found in the power supply unit and the power drive.

The series or universal motor is the only motor that can be used on a-c or d-c. Universal motors are not used in the GFCS Mark 51, so will not be taken up here.

THREE-PHASE INDUCTION MOTORS

The Generator Power Motor is a three-phase induction motor and has a "squirrel-cage" rotor. A rotating magnetic field in the stator induces a voltage in the shorted conductors of the rotor, causing current to flow and magnetic fields to be set up in the rotor. The magnetic field set up in the rotor and the rotating stator field, causes motor action.

The rotor will move in the same direction as close to the rotating stator field as its weight and its load will carry it. The percentage difference between the speed of the rotating stator field and the rotor speed is called "slip."

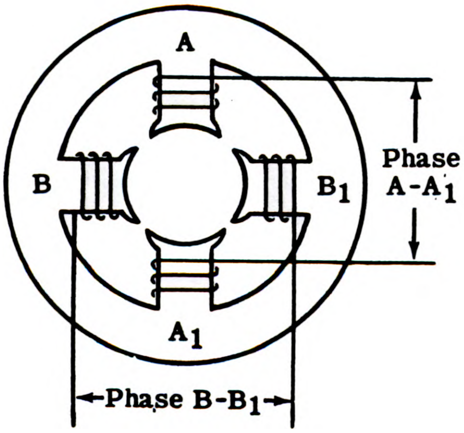
The speed of the rotor depends upon the torque requirements of the load. The bigger the load, the stronger the turning force needed to rotate the rotor. The turning force can increase only if the rotor-induced emf increases, and this emf can increase only if the magnetic field cuts through the rotor at a faster rate. To increase the relative speed between the field and rotor, the rotor must slow down. Therefore, for heavier loads, the induction motor will turn slower than for lighter loads. Actually, only a slight change in speed in necessary to produce the usual current changes required for normal changes in load. This is because the rotor windings have such a very low resistance. As a result, induction motors are called "constant speed motors."

To reverse the direction of rotation, simply reverse any two leads.

SPLIT-PHASE INDUCTION MOTOR

No "two-phase" motors are to be used in this course but they will be taken up to help clarify split-phase motors.

A two-phase induction motor has its stator made up of two windings, which are placed at right angles to each other around the stator. The simplified drawing illustrates a two-phase stator.



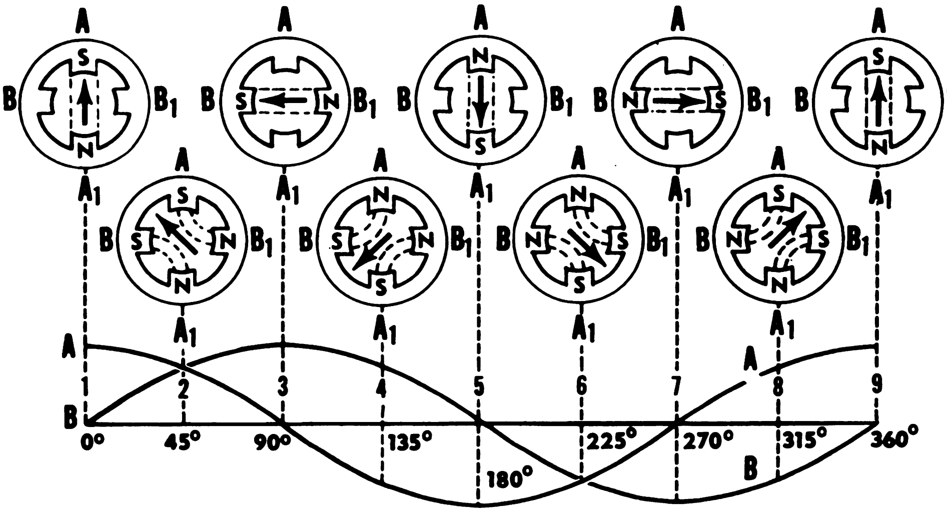
TWO-PHASE INDUCTION MOTOR

The diagram shows a graph of the two alternating magnetic fields which are displaced 90 degrees in phase. The waveforms are lettered to correspond to their associated phase. At position 1, the current flow and magnetic field in winding A-A_1 is a maximum, and the current flow and magnetic field in winding B-B_1 is zero. The resultant magnetic field will, therefore, be in the direction of the winding A-A_1 axis. At the 45-degree point (position 2), the resultant magnetic field will lie midway between windings A-A_1 and B-B_1, since the coil currents and magnetic field in winding A-A_1 is zero and the magnetic field in winding B-B_1 is a maximum. Now, the resultant magnetic field lies along the axis of the B-B_1 winding as shown. The resultant magnetic field has rotated through 90 degrees to get from position 1 to position 3.

At 135 degrees (position 4), the magnetic fields are again equal in amplitude. However, the magnetic field in winding A-A_1 has reversed its direction. The resultant magnetic field, therefore, lies midway between the windings and points in the direction as shown. At 180 degrees (position 5), the magnetic field is zero in winding B-B_1 and a maximum in winding A-A_1. The resultant magnetic field will, therefore, lie along the axis of winding A-A_1 as shown.

From 180 degrees to 360 degrees (position 5 to 9), the resultant magnetic field rotates through another half cycle and completes a revolution.

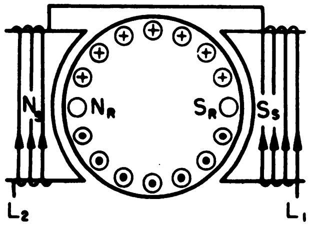
Thus, by placing two windings at right angles to each other and by exciting these windings with voltages 90 degrees out-of-phase, a rotating magnetic field will result.



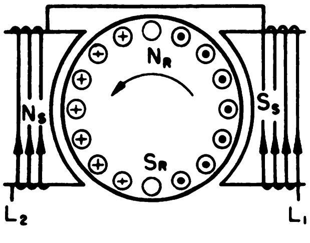
GENERATING A ROTATING MAGNETIC FIELD

Single-phase motors are divided into two groups. Induction motors use the squirrel-cage rotor and a suitable starting device, such as the centrifugal switch in the air-pump motor. Series motors resemble d-c machines because they have commutators and brushes.

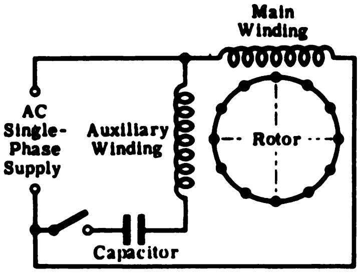
A single-phase induction motor has only one stator winding and, therefore, the magnetic field generated does not rotate. A single-phase induction motor with only one winding cannot start rotating by itself. Once the rotor is started rotating, it will continue to rotate and come up to speed. A field is set up in the rotating rotor which is 90 degrees out of phase with the stator field. The two fields together produce a rotating field which keeps the rotor in motion.



A single-phase source may be split by capacitor action to make an induction motor run similar to a two-phase motor. Some split-phase motors are capacitor start and others are capacitor start-capacitor run.



In order to make a single-phase motor self starting, a starting winding is added to the stator. If this starting winding is placed in series with a condenser across the same line as a running, the current in the starting winding will be out of phase with the current in the running winding. As a result, a rotating magnetic field will be generated and the rotor will rotate. Once the rotor comes up to speed, the starting-winding circuit can be opened and the motor will continue running as a single-phase motor. If the capacitor is installed in the starting winding at all times, the motor is capacitor start-capacitor run.



The cooling motors in the power drive are capacitor start-capacitor run.

JOB SHEET # 26

1. State the four phase-type motors familiar to the FT.

   a. ________________________ b. ________________________

   c. ________________________ d. ________________________

2. How many degrees are there between the stator windings of a three-phase motor?

   ________________________.

3. From what source does a synchronous-motor get its supply?

   ________________________.

4. Briefly, how is current set up in a squirrel-cage rotor?

   ____

   ____

5. What type rotor is used in the generator-power motor in the power drive?

   ____

6. In what direction does the rotor of a three-phase induction motor turn in relation to its rotating field? ________________________

7. How can the direction of rotation of a three-phase motor be reversed?

   ____

8. The windings of a split-phase motor stator are displaced by____degrees.

9. The windings of a two-phase motor stator are displaced by____degrees.

10. What type motor is employed in the air pump unit of the GFCS Mk 51?

    ____

    ____

    ____

11. What type field does a single-phase motor employ?

    ____

SECTION VI

TOPIC 6

POWER CONTROL DEVICES

A. You have learned:

1. About d-c generators
2. About d-c motors
3. About transformers
4. About a-c motors

B. You are learning:

	References
1. The types, uses and construction of the switches found in the GFCS Mk 51	OP 821A, pages 103 to 106; 110 NavPers 10622-B, pages 236 to 238
2. The types of fuses found in the GFCS Mk 51	OP 821A, pages 103 to 106 OD 4429, page 31
3. The types, uses, and construction of the relays found in the GFCS Mk 51	OP 821A, pages 103 to 106 OD 4429, page 47
4. The types and uses of circuit breakers	NavPers 10622-B, pages 236 to 238

SWITCHES

Switches are made in many different sizes and may run from a small microswitch to the larger power switches. Of the many different types in use in the Navy we will be concerned primarily with the ones used in Gun Fire Control System Mk 51.

The Main Disconnect Switch is a five-pole switch on the side of the controller unit. This switch is interlocked with a metal bar which prevents the main disconnect switch from being thrown on whenever the door of the controller unit is opened. The purpose of being built this way is to prevent anyone from working inside the controller unit when there are dangerous high voltages. The main disconnect switch also energizes the 440-volt a-c supply and one side each of the 115-volt reference voltage for train and elevation.

The Selector Switch is located on the power drive and has five sets of contacts which can be placed in three positions; Automatic, Local Power, and Manual. This switch is a rotary-type switch commonly found in fire control switchboards.

The Door Interlock Switch is another safety device which will open the 115-volt a-c reference supply whenever the door of the amplifier cabinet is opened.

The Start-Stop Switch is a spring-loaded switch located on the mount. The start switch makes contact when held down, but will spring back when pressure is released. It controls the starting circuit, which energizes the line contactor on starting. The stop button breaks contact when held down, but springs back and restores contact when released. It breaks both the starting and running circuits.

The ON-OFF Switch of the air supply unit is a two-position rotary switch used to supply 115 volts a-c to the air supply unit to drive the air pump motor and energize a step-down transformer whose secondary voltage of 10 volts a-c is used for heater and illumination supply in the Gun Sight Mk 14.

FUSES

A fuse is an electrical safety device which protects a circuit from burning up because of excess current. The GFCS Mk 51 uses a cartridge-type fuse which contains a metal filament. It will burn out and open the circuit if an excess current passes through it. Most fuses are of the non-renewable type and must be thrown away, once the filament burns out. The renewable type may be disassembled and a new filament inserted. Fuses are of various physical size and construction and are generally rated as to their current-passing ability.

RELAYS

Relays utilize the principle of attraction of a metal containing iron to an electromagnet. You will remember from the past studies that an electromagnet may be constructed by winding a conductor around an iron core. Whenever current is applied to the coil, attraction will occur and the iron core will jump toward the coil. Whenever the current in the coil falls below a certain value, the core will drop out. If contacts are placed on the core and at right angles to it, then whenever the coil is energized the core will cause various circuits to be either completed or opened. This principle is used in most all relays in the GFCS Mk 51.

The Overload Relay is a special type which is used to protect the generator power motor from burning out. This relay contains a thermal device which will cause the relay to drop out if the current passing through exceeds a rated value. The overload relay is automatically reset whenever the thermal device cools off. Another thermal device is in the circuit of the drive motor to prevent it from drawing an excess of current also.

THERMOSTATS

A thermostat is a device that electrically regulates temperature. Such a device is found within the Gun Sight Mk 14 to control the temperature of the damping fluid of the gyros.

CIRCUIT BREAKERS

A circuit breaker is a special type of relay that has the function of a fuse--to protect a circuit from overload. They are usually found aboard ship in power distribution panels. Once a circuit breaker trips out, it must be set manually.

JOB SHEET NO. 27

Answer the following questions:

1. In what position must the door of the Magnetic Controller be in order to throw the Main Disconnect Switch ON?

   ____

2. What voltages are controlled by the Main Disconnect Switch?

   a. ____________________

   b. ____________________

3. What are the three positions of the Selector Switch mounted on the Power Drive?

   a. ____________________

   b. ____________________

   c. ____________________

4. What is the main purpose of the Door Interlock Switch?

   ____

5. What type of switch is the ON-OFF Switch of the Air Supply Unit?

   ____

6. A fuse is an electrical ____________________

7. What causes the Under Voltage Relay in the Magnetic Controller to drop out?

   ____

8. When will the Overload Relay drop out?

9. What prevents the d-c Drive Motor from drawing an excess current?

   ____

10. How is the Overload Relay in the Magnetic Controller reset?

    ____

SECTION VI

TOPIC 7

CABLES

A. You have learned:	References:
1. That power determines the size of an electrical component.	
2. That opens, shorts, and grounds are circuit casualties.	
3. That colors and symbols designate component values.	
4. That a circuit has a path for current flow.	
B. You are learning:	
1. Classification of cables.	NavPers-10722-B, pages 40 and 41; 378 to 380
2. Cable construction.	OP 821A, fig. 177 NavPers-10164-A, pages 289 to 292 NavPers-10622-B, pages 40 and 41; 378 to 380
3. Cable coding methods.	NavPers-10622-B, pages 40 and 41; 378 to 380
4. Cable maintenance instructions.	

CLASSIFICATION OF CABLES

Cables are used in Fire Control and other departments aboard ship for the transmission of electrical energy from one point to another. The design of cables depends upon the type of electrical energy they are going to carry, and also where and how they are going to be used. As a result, cables vary greatly in their electrical and physical characteristics. Cables connect directors, sights, power drives, gun mounts, motors, generators, and all types of electrical equipment. When cables become faulty, the system is made inoperative, and equipment may be damaged.

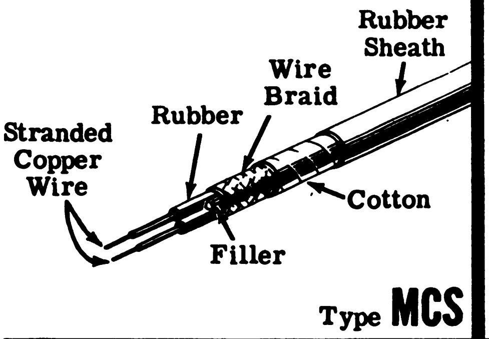
Cables are classified according to types of insulation used and construction characteristics. Rubber-insulated cables are used for fixed installations, such as directors and gun mounts, where flexibility is required. Oil-resistant insulation is used to protect cables from oil and grease. Braided metal armor protects the cable from mechanical damage, heat, and flame.

Stationary cables are usually armored, and flexible cables are rubber or synthetic covered in the power drive. Conductors in most cables are stranded to allow the cable to be bent.

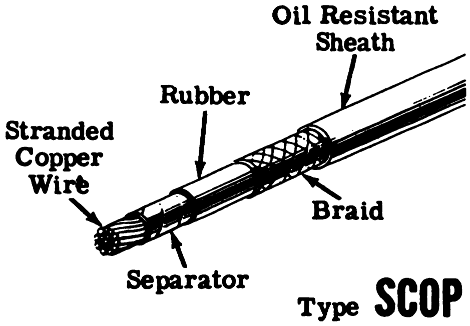
CABLE CONSTRUCTION

The construction of cables depends on the type of electrical energy to be carried, also where and how they are going to be used.

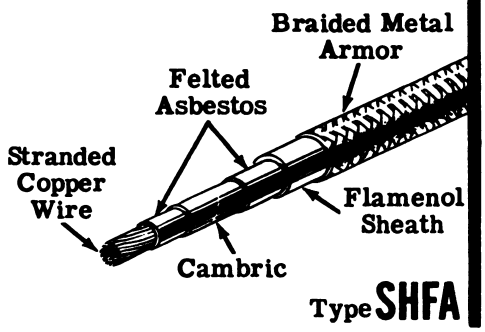
The illustrations below show construction of some typical Navy cables with their identification code.



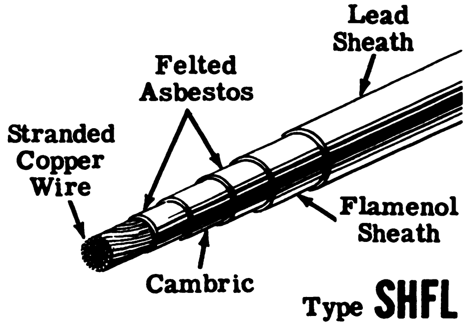
Type **MCS**



Type **SCOP**



Type **SHFA**



Type **SHFL**

CABLE CODING METHODS

Cables are tagged for DAMAGE CONTROL purposes and as an aid in tracing. Tags are colored, numbered, and lettered.

Cable tags are located on cables before and after entering a bulkhead or deck, before entering junction boxes, at the source, and at the load.

RED tags are vital and, if disabled, would impair fighting efficiency of the ship. Yellow tags are semivital. Gray or neutral tags are nonvital.

Ships built prior to 1950 have a different code. For those ships, BLUE is VITAL, green is semivital, and gray or neutral is nonvital.

An example of tag marking is: G-GS-7.

G--Gunnery or "Fire Control."
GS-Dual-purpose battery.
7--Cable number 7 in that circuit.

Lead designations identify each conductor. Use this sample number for breakdown.

19-GE-2-1-6-5

(1)	(2)	(3)	(4)	(5)	(6)
19	GE	2	1	6	5

(1) Quantity transmitted
(2) System or battery

(3) Station from which a circuit comes or to which it goes
(4) Instrument within that station
(5) (When present) Indicates station from which the cable is coming.
(6) Specific lead

Lead designations may change slightly from ship to ship, so learn the code on YOUR ship as soon as possible.

Cable types are indicated by letters and numbers.

a. First designator. Fill in meaning:

(1) S ____________ (2) D ____________

(3) T ____________ (4) F ____________

(5) M ____________ (6) G ____________

(7) TT ____________

(8) TP ____________

b. Other designators. Fill in meaning:

(1) A ____________ (2) B ____________

(3) C ____________ (4) F ____________

(5) HF ____________

(6) IC ____________

(7) O ____________

(8) P ____________ (9) R ____________

(10) S ____________

c. Numeral designators.
  (1) Cables having first designator S, D, T, or F indicates approximate conductor size in thousands of circular mils (CM)
  (2) Cables having first designator M or G indicates number of conductors.

What type of cable do the following codes indicate?

a. MCOP-7 ____________

____

____

b. DHFA-4 ____

____

____

____

In multiconductor cables, the color of the separate conductors indicates the conductor number.

CABLE MAINTENANCE INSTRUCTIONS

In cable maintenance, as well as in any other type of electrical maintenance, readings taken when the system is operating at peak performance, are good guides for future checks.

Insulation resistance must be high at all times. Low readings are usually caused at the end of a cable, especially in junction boxes exposed to the weather and to salt spray. Insulation resistance checks must be made periodically and the results logged for comparison to future readings. Insulation resistance checks must be made with a megger between ground and the circuit under test.

Breaks and high-resistance connections such as cold-solder jobs, loose connections, and dirty connections are found by "continuity checks" and are made with an ohmmeter.

WARNING: NEVER USE AN OHMMETER OR MEGGER ON A "HOT" CIRCUIT.

SECTION VI

TOPIC 8

TEST EQUIPMENT

A. You have learned:	References:
1. That magnets attract and repel	
2. That a current carrying wire generates a magnetic field	
3. The principles of motor action	
4. That ammeters measure current	
5. That voltmeters measure voltage	
6. That ohmmeters measure resistance	
B. You are learning:	
1. How the different types of meters are used, and precautions to take when using meters	NavPers-10622-B, pages 259 to 261
2. How meters use the effects of heat, chemical action, and magnetism to measure electricity	NavPers-10622-B, pages 261 to 268
3. Ammeter principles and use	NavPers-10622-B, pages 269 to 273
4. Voltmeter principles and use	NavPers-10622-B, pages 274 to 277
5. Chmmeter principles and use	NavPers 10622-B, pages 279 to 282
6. About ME 48/U and 449A multimeters	
7. Megger principles and use	NavPers-10622-B, pages 282 and 283
C. You will acquire skill in:	
1. Reading, using, and caring for meters.	

INTRODUCTION TO TEST EQUIPMENT

Electric meters are a simple and useful method of detecting and measuring electrical effects. You will make constant use of them in your work with electricity and electronics. In other words, meters are accurate, delicate tools. Treat them as such.

The meter movement is the device that detects and measures the effect of electricity to generate heat, chemical action, or the effect that interests the FT most--magnetism. The scale is marked in numbers which indicate electrical quantities, and the pointer moves across the scale to indicate just how much electrical effect is taking place.

The amount of current flowing through a meter causes the pointer to indicate how much current, voltage, or resistance is being measured. The design of the meter determines which one of the specific quantities it will measure. Ammeters measure current, voltmeters measure voltage, ohmmeters measure resistance, and multimeters are designed to measure all three quantities, one at a time, through a switching or plug-in arrangement.

Ammeters measure current in amperes, milliammeters in milliamperes, and microammeters in microamperes.

Voltmeters measure voltage, or electrical pressure, in volts. Smaller values than one volt are measured with a millivoltmeter or microvoltmeter.

Ohmmeters measure resistance in ohms. Meggers are a special type of ohmmeter designed to test insulation resistance in millions of ohms or "megohms."

Meters are delicate, costly, and difficult to repair or replace. Be careful not to drop them or bump them against other objects. Handle with care!

Meters are connected in circuits in different ways. Ammeters are always connected so that the circuit current flows through the meter or, in other words, they are connected in series. Voltmeters are connected across or in parallel with any of the circuit components across which it is desired to measure voltage.

Ohmmeters have their own power supply and are connected in a dead circuit only. When measuring resistance in a circuit, make sure there is no parallel path across the circuit. If there is a parallel path, part of the current will flow through the parallel branch, and inaccurate readings will be the result. Never connect an ohmmeter in a "hot" circuit, for this will cause damage to the meter.

Short circuit is a fault which occurs in electrical circuits whenever some part of the connecting wires touch each other, or a parallel component resistance decreases to zero in such a way that the electrons do not flow through the load but flow through a shorter path from one side of the source of emf directly to the other side. Since there is no resistance, the current flow becomes so large that much heat is generated, possibly causing the line or the source, or both, to be destroyed.

An open circuit is one in which there is an incomplete circuit for current flow. There may be a break or poor connection in the line, in the load, or in the source, and the current cannot jump across this open portion of the circuit.

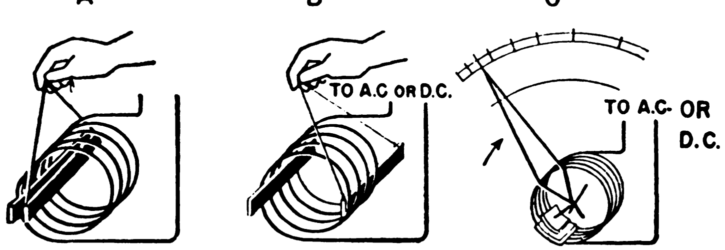
Meters may be damaged if too low a scale is used. Always make sure the meter you are using has a high enough scale to indicate the value of electricity. When in doubt, use a larger scale.

BASIC METER MOVEMENTS

Five basic meter movements are taken up here. The ones most extensively used will be taken up more in detail.

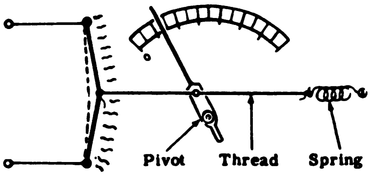
The "moving-vane" type meter movement can be used on a-c or d-c current or voltage. It operates on the principle of magnetic repulsion between like poles.

The following sketches illustrate the moving-vane principle. "A" shows a de-energized condition where there is no action between the two unmagnetized pieces of iron. "B" shows current passing through the coil, magnetizing the iron pieces alike and causing the suspended iron piece to be repelled. As current increases through the coil, the iron pieces become stronger magnets and the suspended piece is repelled farther. "C" is the developed meter as it actually is. The movable iron piece and the indicator needle are mounted on a jeweled shaft which has an angular movement proportional to the current through the coil.



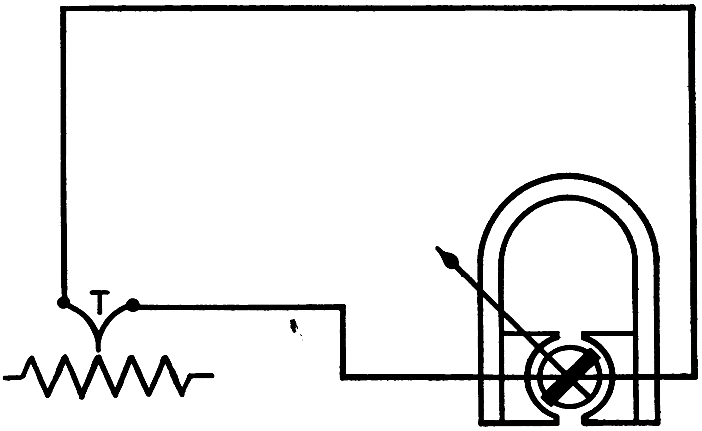
MOVING VANE METER MOVEMENT

The "hot-wire" type meter movement utilizes the heating effect of current flowing through a resistance to cause needle deflection. The wire expands as it heats, allowing the spring to move the needle. It can be used to measure a-c or d-c current only.



HOT-WIRE METER MOVEMENT

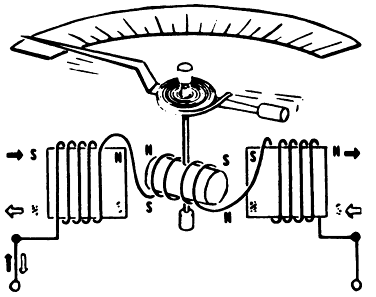
The thermocouple meter consists of a resistance wire across the meter terminals, which heats in proportion to the amount of current flow in the circuit under test. Attached to this heated resistance wire is a small thermocouple junction of two unlike metals which connect across a very sensitive d-c meter movement. The current being measured flows only through the resistance wire, not through the meter movement. The pointer turns in proportion to the amount of heat generated by the resistance wire, and the scale is marked off to indicate the current flow in the circuit.



THERMOCOUPLE METER MOVEMENT

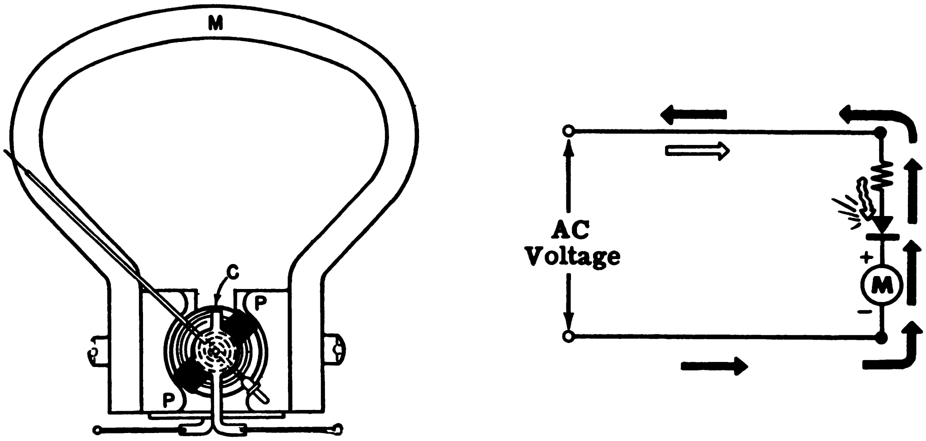
Electrodynamometer meter elements use the motor action of two fields. The stationary field is up by two large stationary coils and the moving field is set up by a small movable coil pivoted in the center of the large coils. This light coil has opposing spiral springs and carries the needle indicator on its shaft.

The current to be measured flows in all three coils because they are in series. Because the current through all coils are the same, the POLARITIES OF THE COIL ARE ALWAYS THE SAME. Repulsion is produced and the movable coil turns. This meter can be used on d-c because of repulsion and also on a-c since the polarites of both its coils "reverse together."



ELECTRODYNAMOMETER METER MOVEMENT

The D'Arsonval meter movement consists mainly of a very accurate movable coil mounted between the pole pieces of a "permanent" magnet. The coil carries the current of the circuit, and has the indicator needle attached. The D'Arsonval movement--or galvanometer, as it is sometimes called--can be used on d-c only, as it is. To convert to a-c use, a small rectifier is connected in series with the sensitive element and the scale is calibrated to read effective values of a-c.



D'ARSONVAL MOVEMENT AND A-C APPLICATION

Ammeters employ low-resistance "shunts" in parallel with the sensitive element, to increase the scale.

Voltmeters and ohmmeters employ high-resistance multipliers in series with the sensitive element, to vary the scale.

The most accurate portion of the meter scale is center scale. The usable portion of the scale is approximately 40 degrees each side of center scale. When the needle indicates near the ends of the scale, the scale should be changed.

Reading a meter scale from an angle causes an error, called ____________________.

Estimating meter reading between two scale divisions is called ____________________ ____________________.

"Zero set" adjustments correct the sensitive element of meters for changes in temperature. This is a screw-driver adjustment and should be checked each time before using any meter.

AMMETERS

Ammeters are connected in ____________________ with the load. They carry all, or a definite fraction of, ____________________ current.

To increase the scale of an ammeter, a ____________________ resistance shunt is connected across the meter terminals.

Moving-coil ammeters can handle about ____________________ directly without a shunt. The formula for calculating shunt resistance is:

$$R_S = \frac{R_m}{N-1}.$$

When:

$\underline{R_s}$ = shunt resistance
$\underline{R_m}$ = meter resistance
$\underline{N}$ = the multiplier

Ammeters are always connected in ____________________ with the load. If connected across a line, the ammeter will be ruined and the circuit may be. __________.

VOLTMETERS

Most voltmeters employ the ______________________ type meter movement. This basic meter movement uses a ____________________ in series with it so it can be used to measure a-c.

To use a vacuum tube voltmeter, it has to be provided with a __________________ source.

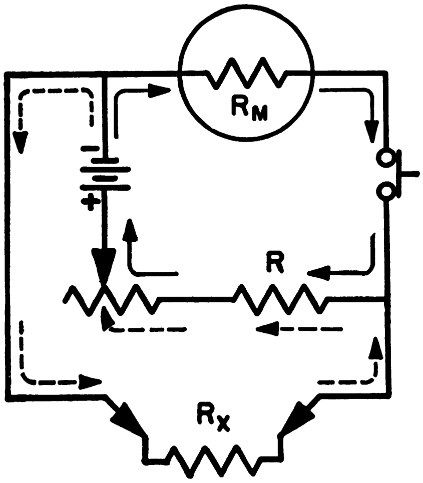
Voltmeters used to test potentials in electronic circuits must have at least ________ __________________ ohms per volt.

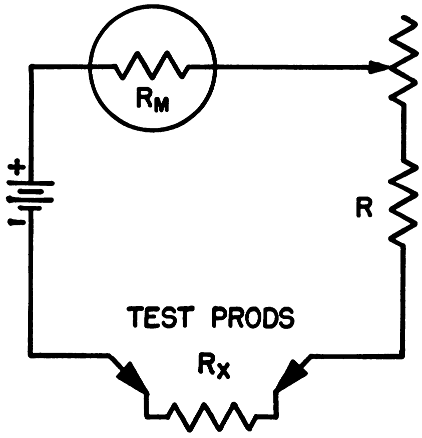
The higher the voltage scale to be used, the ____________________ the resistance value of the multiplier has to be. Regardless of the scale used, the maximum current that can flow through the meter element remains the same. When in doubt as to the approximate value of voltage to be measured, use the HIGHEST scale!

OHMMETERS

NEVER use an ohmmeter on a ______________ circuit! They use a battery as their souce.

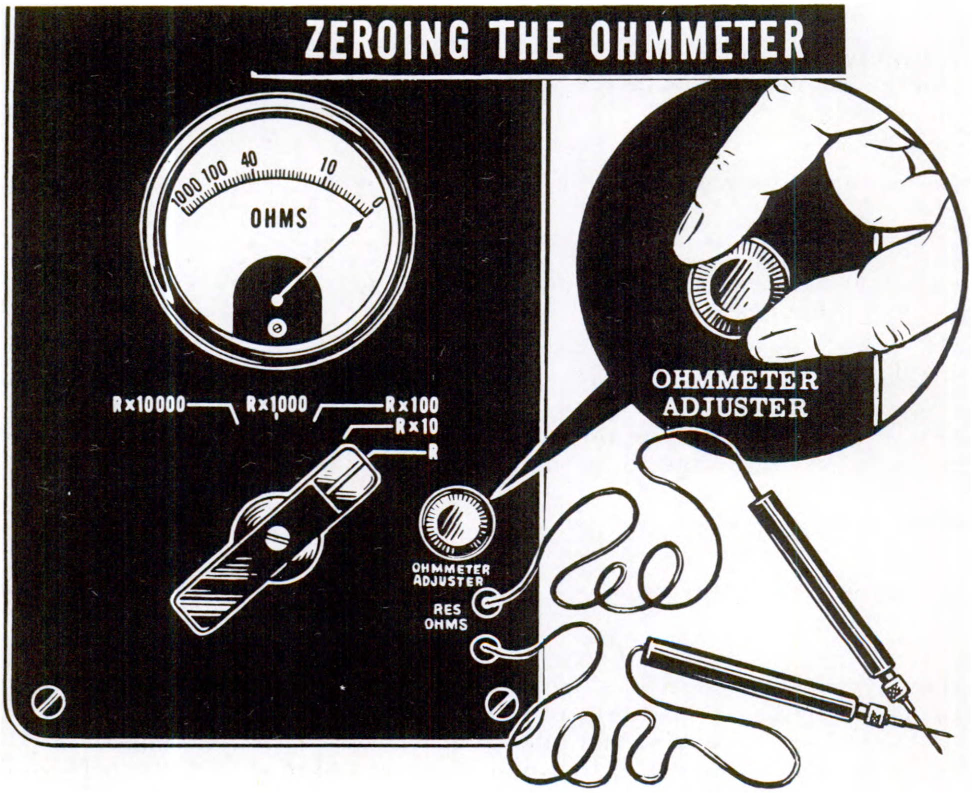
The series-type ohmmeter has the multiplier resistor, battery, and meter element connected in series with the unknown resistance. For series-type ohmmeters, full scale deflection is "zero" on the scale, and maximum current flows through the meter element at this time. To increase the scale, the multiplier resistance is decreased in the series-type ohmmeter.





The shunt-type ohmmeter has the battery and multiplier resistance in ______________ ________ with the meter element. The unknown resistance is connected in ______________ with the meter element. A switch is provided to open the battery circuit when not in use. To increase the scale on the shunt ohmmeter, the multiplier resistance is ______________ .

The adjustment rheostat provided to compensate for decrease in battery capacity is called the ____ . This adjustment is made before using the ohmmeter on each scale.

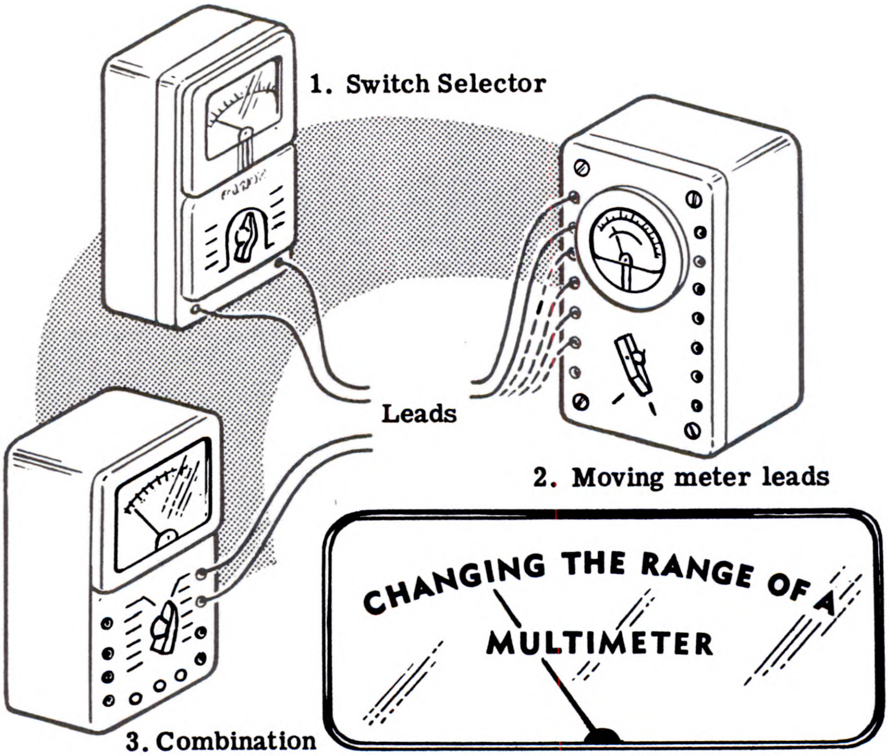


The ohmmeter is the meter to use when checking a resistor value or for making continuity checks.

MULTIMETERS

To test electronic circuits (for example, a rectifier circuit), resistances, a-c and d-c voltages, and currents are measured. Because the values of resistance, voltage, and current to be measured differ greatly, several ohmmeter, voltmeter, and milliammeter ranges are required. A multimeter is a combination volt-ohmmeter-milliammeter, having various ranges for measuring voltages, resistances, and current. The multimeter has a single-meter movement, with various shunt and multiplier combinations used to obtain different meter ranges.

Multimeter ranges are selected in three ways: (1) by means of a switch, (2) by changing meter lead connections from one set of pin jacks to another, and (3) by a combination of switching and moving meter leads to various pin jacks or meter terminals.



By using these methods of changing its range, a single basic meter movement may be used as an ohmmeter, voltmeter, or milliammeter. (Currents to be measured in electronic circuits usually are in milliamperes.)

When used as a voltmeter, the switch connects the basic meter movement in series with a multiplier resistor, which determines the voltage range for d-c volts. A rectifier is also switched into the meter circuit on the a-c voltage ranges. When used as a milliammeter, the switch connects a shunt across the meter movement, to increase its range. For the ohmmeter ranges, a battery and a zero-set potentiometer are connected to form a resistance-measuring circuit of the desired range.

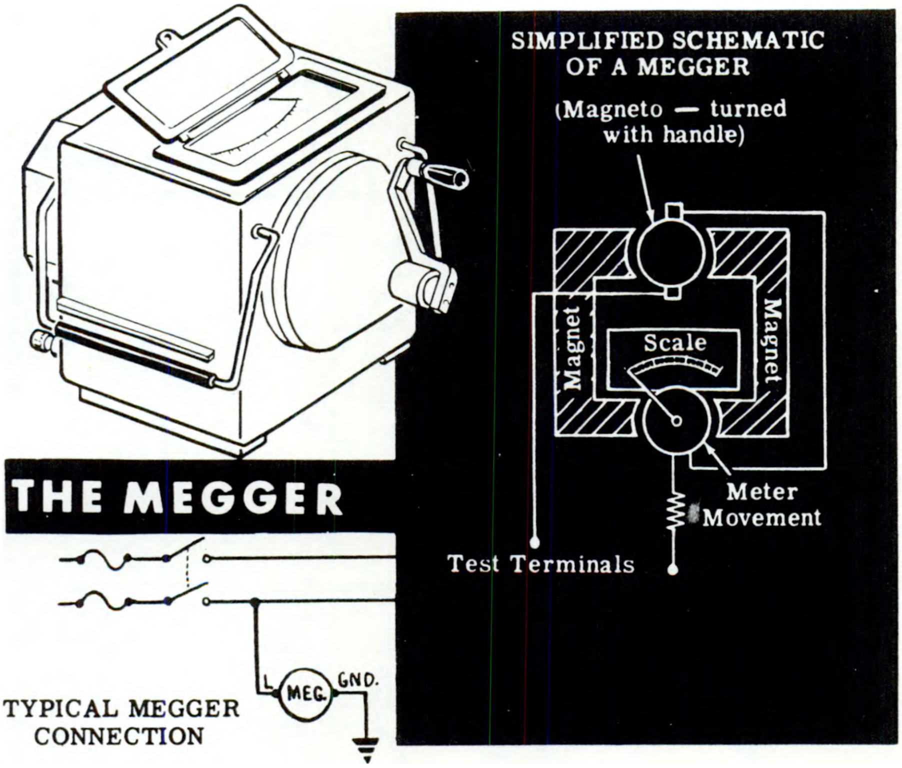
The "model 449" Radio City Products Company multimeter is recommended for testing some power, signal, and transmission circuits. The Navy model ME 48/U is a 20,000-ohm-per-volt meter and can be used to test all the electronic circuits in the power drive.

MEGGERS

The megger is an instrument which is used for measuring insulation resistance, such as the resistance between windings and the frame of electric machinery, and the insulation resistance of cables, insulators, and bushings. The megger consists of two parts: (1) a hand-cranked d-c generator (magneto) or a high-voltage "B" battery, which supplies the voltage for making the measurement, and (2) a special type of meter movement.

Before using the megger, the circuit is voltage checked to make sure it is de-energized because, the megger must only be used on a de-energized circuit. Then both meter leads are connected to ground to ensure a good ground connection and good meter operation. Next, the megger is connected across the circuit to be tested and the hand crank is turned, generating a high voltage across the megger terminals. As a result, current flows through the circuit or insulation being tested. This current flow is measured by the meter movement as it is in an ohmmeter, but unlike the ohmmeter, the megger is calibrated to measure megohms. The normal resistance reading for a circuit insulated from ground is several hundred thousand ohms. If the megger reads low, a ground exists, and the shorted circuit should be replaced.

A "ground" is a reference point for voltage and resistance measurements in electrical circuits. All large metal objects (such as motor housings, switch boxes, and transformer cases) that are associated with electrical equipment are directly connected to the metal of the ship. A megger determines if any of the wires inside a motor or transformer have come in contact with the metal housing (have become "grounded") or are in danger of becoming so.



THE MEGGER

SIMPLIFIED SCHEMATIC OF A MEGGER

TYPICAL MEGGER CONNECTION

SECTION VI

TOPIC 9

SYNCHRO UNITS

A. You have learned:

1. About d-c generators
2. About d-c motors
3. About transformers
4. About a-c motors
5. About power control devices
6. About cables and designation
7. About test equipment

B. You are learning:

	References:
1. What a synchro is	NavPers 10170, pages 225 to 227 OP 1303, pages 7-11
2. How synchro motors and generators work	OP 1303, pages 26-34 OP 821A, pages 36-39 NavPers 10170, pages 233-243 NavPers 10622-B, pages 333-338
3. Synchro motor and generator construction	OP 1303, pages 22-25 NavPers 10170, pages 228-232
4. A basic synchro system	OP 1303, pages 35-50 OP 821A, pages 21, 31, 35 NavPers 10170, pages 239-240
5. What a synchro control transformer is and how it works	OP 1303, pages 65-72 OP 821A, pages 39-42 NavPers 10170, pages 266-274
6. Methods of zeroing synchro units	OP 1303, pages 111-117 and 123-139 OP 821A, page 43

C. You will acquire skill in:

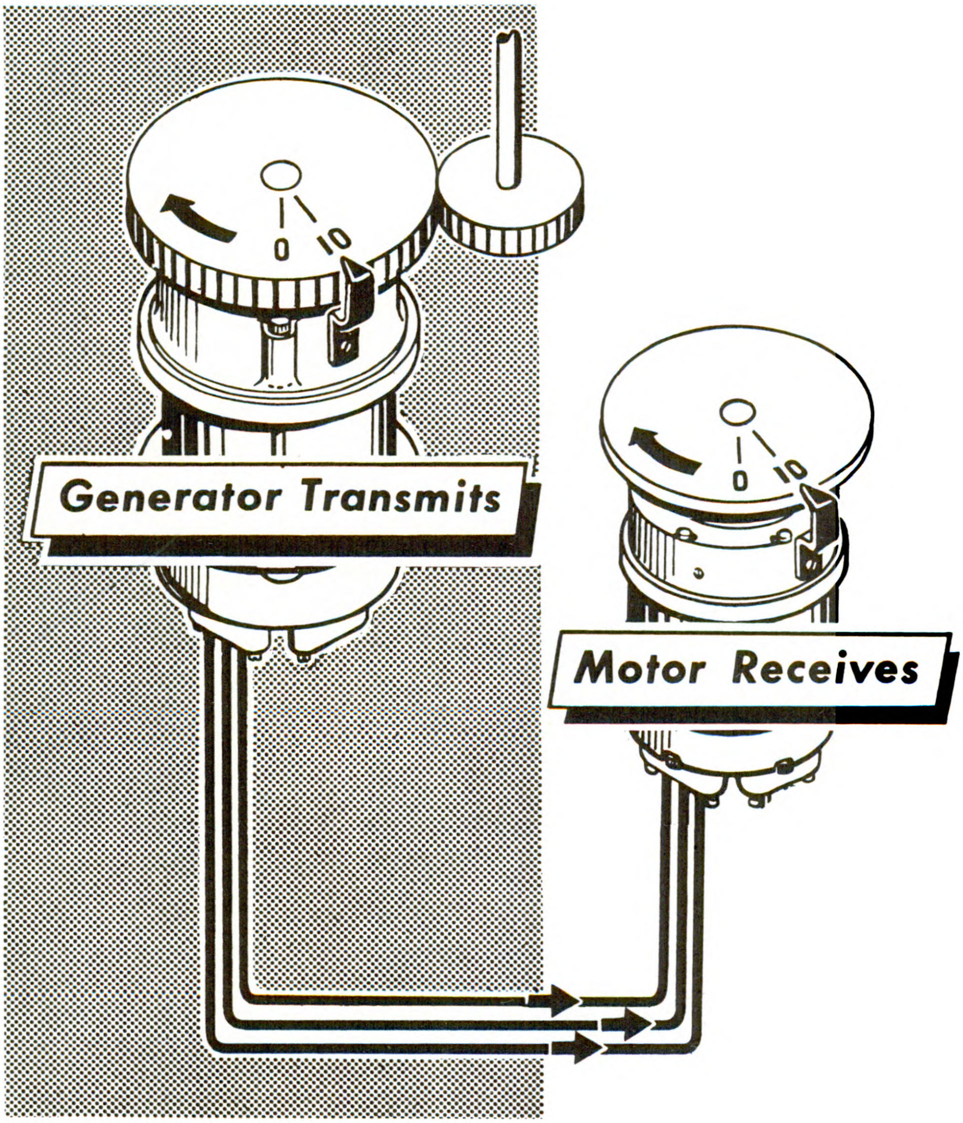
1. Zeroing the synchros in the GFCS Mk 51

INTRODUCTION TO SYNCHROS

Aboard ship, and especially in Fire Control, a device is needed to accurately transmit values from one point to another. For example, Gun Fire Control System Mk 51, to transmit train and elevation values from the director to the power drive we would use mechanical shafts and gears. To transmit the values accurately would require an extremely complex system. The Navy has solved this problem of transmission of quantities between two points by using synchro units.

A synchro is an electrical device used to transmit information accurately and instantaneously. Synchros require very little space, are light weight, and the cables used to connect them may pass through watertight bulkheads without loss of watertight integrity of the ship.

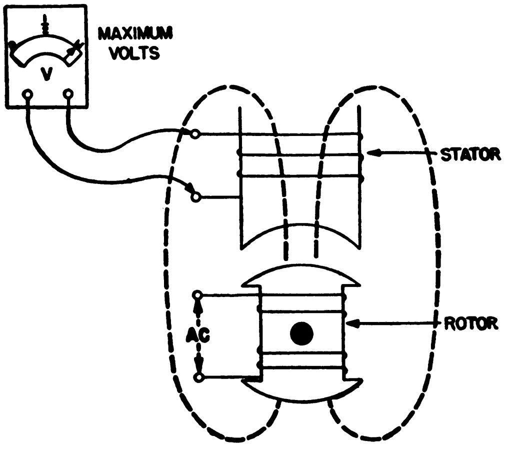
In synchro systems, the synchro generator, by physically displacing its rotor, induces a voltage in its stator windings. This stator voltage is then sent to the stator windings of a synchro motor and causes its rotor to turn the same amount the generator rotor was moved. The torque produced by the motor is very small, however, and must drive a light load. Usually this load is a dial, electrical contacts, or pilot valves of a hydraulic system.



HOW THEY WORK

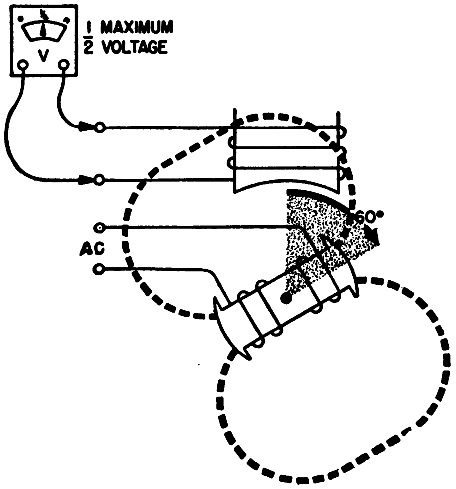
You will remember from the topic on transformers that the primary and secondary coils were always parallel to each other. Transformers are constructed this way so that all the lines of force from the primary windings sweep across the secondary windings, inducing a maximum amount of voltage in the secondary.

A synchro, in all respects, acts just like a transformer. The rotor coil is the primary and is made to rotate within the stator, which is the secondary. If the rotor is parallel to the stator, then by energizing the rotor with a-c, a maximum voltage will be induced in the stator winding.



SYNCHRO ACTION AT 0^o (ROTOR AND STATOR ARE PARALLEL)

If we rotate the rotor 60 degrees, then only one-half of the flux from the rotor will sweep across the stator windings and only one-half of the maximum voltage will be induced in the stator windings.

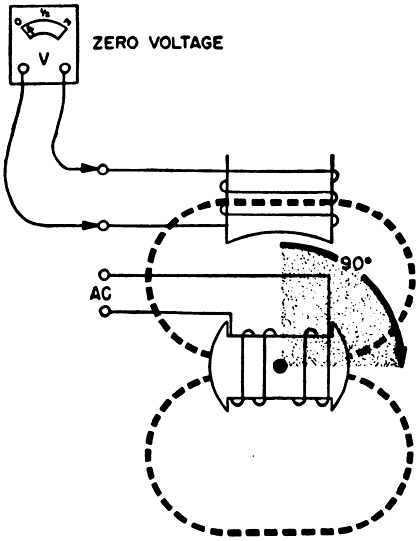


SYNCHRO ACTION AT 60^o

If we rotate the rotors still further, say to 90 degrees, then at this time the rotor and stator are at right angles to each other and there will be no voltage induced in the stator winding.

From the following illustration, you can see an important point in understanding the action of synchros. TRANSFORMER ACTION IN A SYNCHRO DEPENDS ON THE ANGULAR DISPLACEMENT OF THE ROTOR AND STATOR.

An actual synchro contains three stator windings, which are placed 120 degrees apart. This arrangement will give us voltage combinations in the stator windings which are never duplicated at any other position of the rotor.



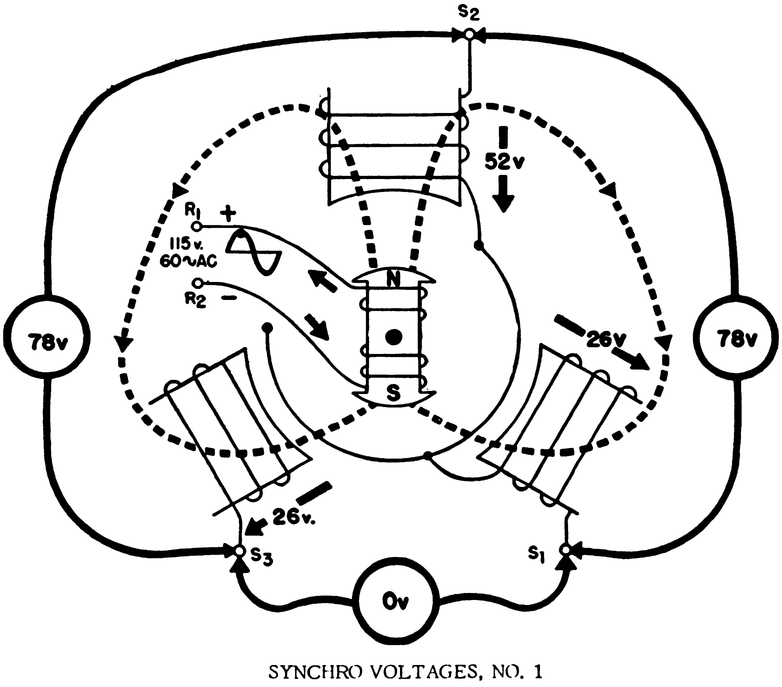
SYNCHRO ACTION AT 90°

All FC synchros--both generators and motors--are energized with 115-volt, 60-cycle, a-c at their R1-R2 leads. And the turns ratio between rotor and stator is standard. This turns ratio, and the 115 volts on the rotor, produce a MAXIMUM of 52 effective volts in any one stator coil. This is standard dope for all FC synchros--remember it.

The following figure shows a synchro with 115 volts a-c applied to its rotor. And the voltmeters show the voltages at the stator leads.

Notice in figure 1 the method of labeling polarities. The dot on the positive alteration of the sine wave means that all polarities are for that instant on the positive alternation. A dot on the negative alternation would reverse all polarities in the circuit. This method of marking a-c circuits makes circuit tracing easy--get used to it now.

Now , find the voltage labels at each stator winding. The S2 winding has the greatest voltage--52 volts. S2 is maximum because the rotor is 0 degree from S2--their axes coincide.



SYNCHRO VOLTAGES, NO. 1

The S1 and S2 windings have 0.5 of this maximum voltage, or 26 volts. S1 and S3 have 0.5 of this maximum because the rotor is displaced 60° from S1 and S3.

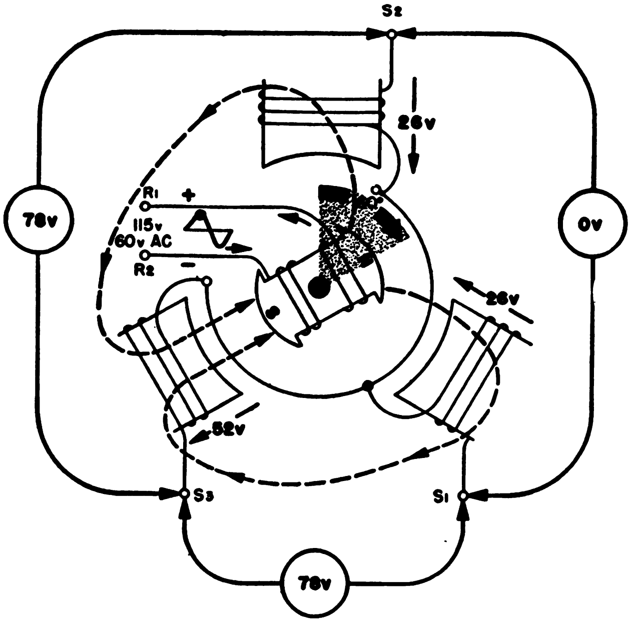
Compare the S2 polarity to the polarity of S1 and S3. They're opposite because an N-pole flux cuts S2, and S-pole cuts S1 and S3. The opposite polarites tell you that the S2 phase is opposite to the S1 and S3 phases.

Now, go back to figure 1 and notice the voltmeter readings. The meters between S1 and S2, and between S2 and S3, read 78 volts. The readings are 78 volts, because the 52 volts of S2 add to the 26 volts of both S1 and S3. But the meter between S1 and S3 reads 0 volts. The S1-S3 reading is zero, because S1 and S3 voltages CANCEL each other --they're equal and opposing.

Now turn the synchro rotor 60 degrees in the clockwise direction--you get figure 2. A 60 degree turn lines the rotor up with the S3 winding.

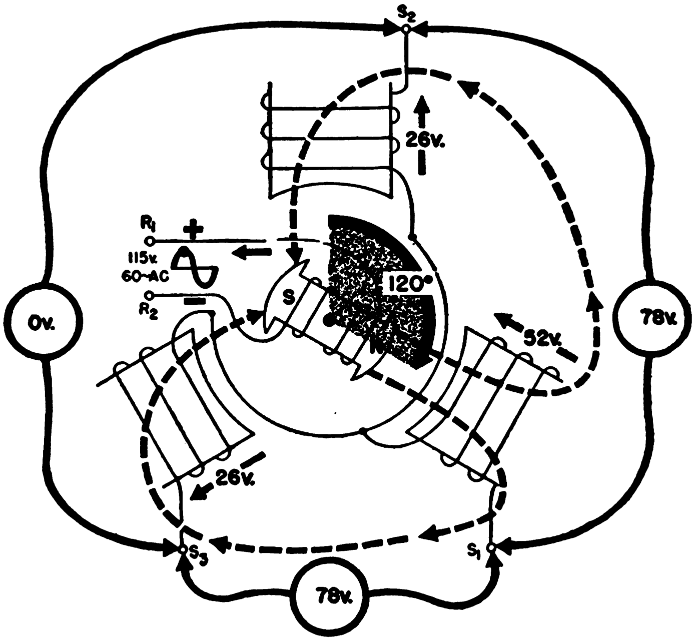
Notice the changed stator voltages. Now S3 is 52 volts, while S1 and S2 are 26 volts. You know why--S3 cuts all the rotor flux, while S1 and S2 cut only one-half the rotor flux.

Notice that S1 REVERSED PHASE as the rotor turned 60 degrees. In figure 1, S1 was cut by the S-pole of the rotor. But in figure 2, S1 is cut by the N-pole. The reversed flux reverses the S1 phase. Here's what happened as the rotor turned. The S1 voltage fell to zero, reversed, then built up to 26 volts of the opposite phase.



SYNCHRO VOLTAGES, NO. 2

Finally, turn the rotor another 60 degrees. Now it's 120 degrees from the original position and you get figure 3. The 120-degree position lines up the rotor with the S1 winding.



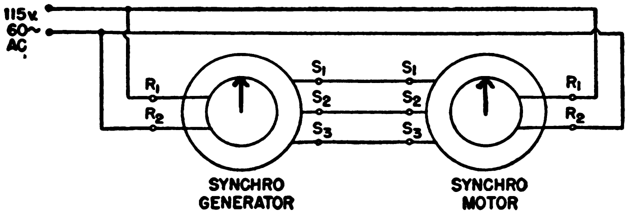
SYNCHRO VOLTAGES, NO. 3

All the voltages and polarities are labeled in figure 3. You figure them out.

Review the voltages induced in each stator coil as the rotor turns. Each stator coil takes its own turn in building up to a maximum voltage, falling to zero voltages, reversing phase, and building up to a maximum again. Be sure to see the relationship between the rotor position and the induced voltages. Every Rotor Position Induces Its Own Set Of Voltages In The Stator.

Remember--you've been looking at both GENERATOR AND MOTORS. The stator voltages are just the same in both units. Because--they're constructed the same and both have 115-volt, 60 cycles, a.c., on their rotors.

Now suppose we connect up a synchro generator to a synchro motor. Both sets of rotor leads are connected to the 115-volt AC supply because you will remember that the rotors are to act as primaries. Each stator lead is connected lead to lead, as were the rotor leads, and will act as secondaries.



TRANSMITTER AND RECEIVER CONNECTED

If both rotors are displaced by the same amount, they are in CORRESPONDENCE. At correspondence, the induced voltages in the two S1 coils are equal--the induced voltages in the two S2 coils are equal--and the induced voltages in the two S3 coils are equal--and the induced voltages in the two S3 coils are equal.

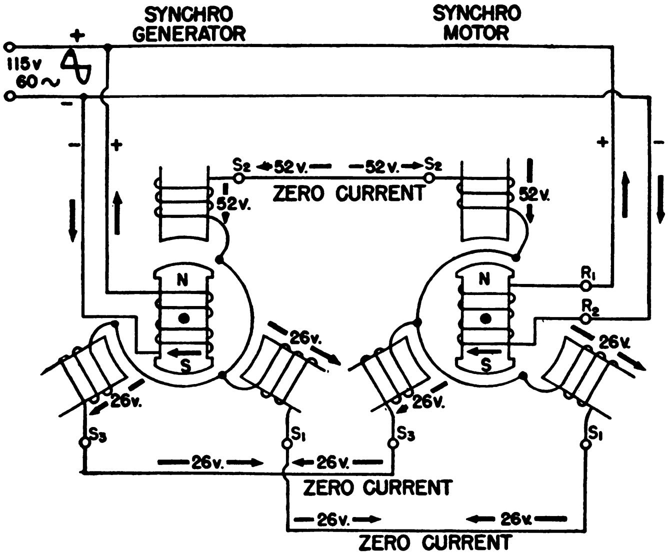
Since the stator voltages are bucking and equal, they cancel each other. Result--no resultant voltages on the stator windings and NO CURRENT in the stators.

But remember that the transmitter rotor is turned and held in position mechanically, whereas the receiver rotor is free to turn. Now, if the two rotors are NOT displaced by the same amount, the voltages across S1-S1, S2-S2, and S3-S3 are NOT equal. And the unequal voltages set up currents in the stator windings. These currents create stator flux fields that exert torque on the rotors. Result--the transmitter rotor remains stationary because it is held mechanically, but, the receiver rotor is turned by the torque.

The turning of the receiver rotor is the important part of synchro action.

Figure 1 shows the transmitter and receiver rotors in correspondence. Both rotors are displaced by 0°. In other words, both rotors are at electrical zero.

Compare the stator voltages and polarities in figure 1. The stator voltages CANCEL each other because S1 equals and bucks S1, S2 equals and bucks S2, and S3 equals and bucks S3. Result--current is zero, no torque is produced, and the rotors remain stationary.

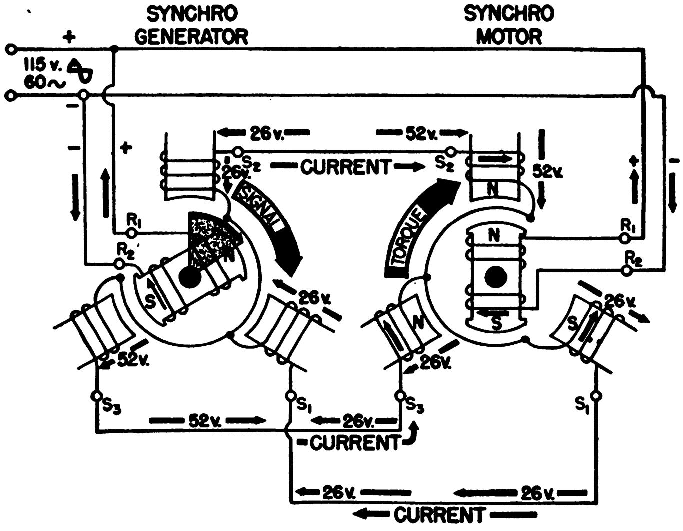


SYNCHRO ACTION, NO. 1

Figure 2 shows the beginning of synchro action. First, the generator rotor is displaced mechanically. This displacement is called signal. The signal can be any amount of displacement, from a fraction of a degree up to 360 degrees. But notice the signal in figure 2--it's 60 degrees.

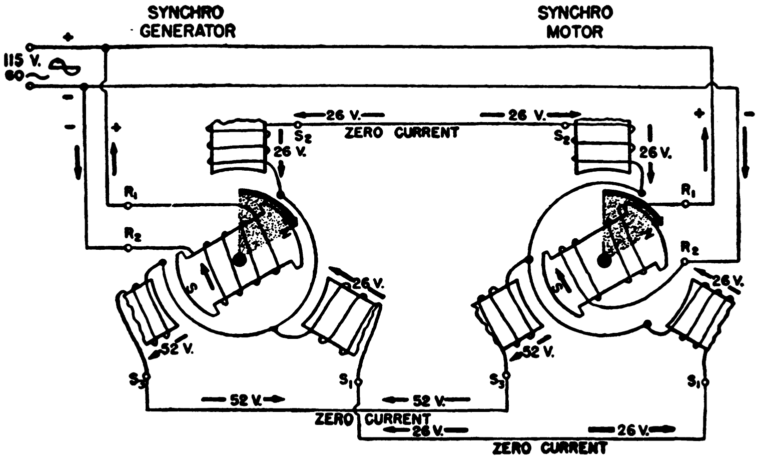
Just as soon as the transmitter rotor is turned, the voltages in the generator stator change. The voltage of the S1 coil decreases, the S2 coil voltage reverses phase, and the S3 coil voltage increases. Immediately, current flows between the two stators--always in the direction determined by higher voltage.

Trace out the stator currents for the 60-degree signal. Notice what the stator currents do in the receiver. The stator currents set up an N-pole at S2, an S-pole at S1, and an N-pole at S3. These stator poles create the torque on the receiver rotor. Result--the receiver rotor turns in the direction of the torque.



SYNCHRO ACTION, NO. 2

Figure 3 shows how far the receiver rotor turns. The torque turns the receiver rotor until the stator voltages in the transmitter and receiver are again equal--until current stops because the voltages cancel each other. You know when the stator voltages are equal--when the rotors are in correspondence. Thus, the receiver rotor turns 60 degrees, the same amount as the signal at the generator.



SYNCHRO ACTION NO. 3

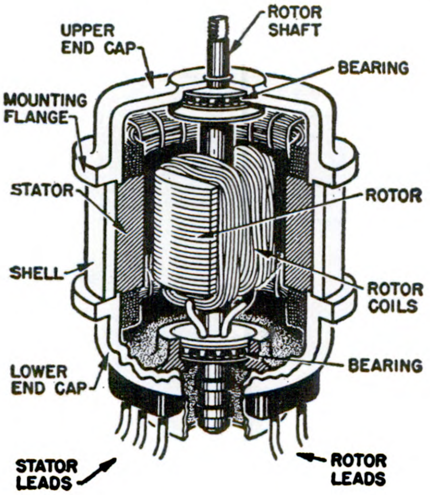
Here's a review of synchro action. Any signal at the transmitter unbalances the stator voltages. The unbalanced voltages produce current in the stator coils. This current sets up stator flux fields. These flux fields exert a torque on the receiver rotor. The torque turns the receiver rotor until its position corresponds to that of the transmitter rotor. Thus, the receiver follows every move of the transmitter rotor. In other words, the receiver delivers the signal that was put in at the transmitter.

MOTOR AND GENERATOR CONSTRUCTION

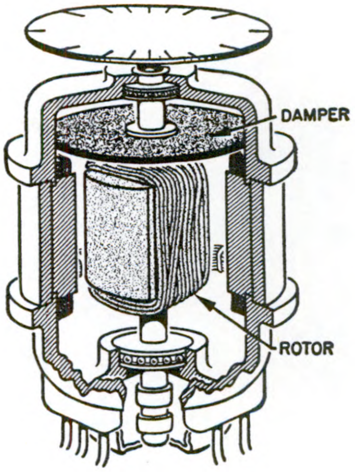
The motor and generator are identical in construction with but one exception--the motor, or receiver, has a damper connected to its rotor. Here's the reason for the damper on the motor's shaft. The motor is driven by an electrical signal from the generator.

Inertia can cause the motor to overdrive, causing oscillation as it reverses to correct the overdrive. The damper prevents oscillation by constantly decreasing the overdrive.

Below is a picture showing the construction of a synchro transmitter and a synchro receiver. You can see how they differ in physical construction.



SYNCHRO TRANSMITTER



SYNCHRO RECEIVER

There is a big difference, however, in the required tolerance of the ball bearings within synchros. In a synchro receiver it must be able to synchronize exactly to a very small signal. You will remember that the torque of a synchro is very small and, therefore, the rotor of a synchro receiver must be practically frictionless. This is done by using precision ball bearings. The rotor of a transmitter should not be interchanged with the rotor of a receiver because the bearings within a generator, although they are of high quality, do not meet the precision requirements of synchro motor bearings.

SYNCHRO SYSTEMS

In practical applications aboard ship, many cases may be found where one synchro generator is used to drive numerous synchro motors. In a case such as that, the one generator stator would be carrying all the currents. This means we need a bigger transmitter. A size 1 transmitter can drive only two size 2 receivers. A size 5 transmitter can drive only two size 5 receivers. However a size 6 transmitter can drive nine size 5 receivers, or a size 7 transmitter can drive eighteen size 5 receivers.

Regardless of the size and number of synchros used, all installations use a standard type of connection. All rotor leads are connected to the same supply line--all R1 leads to one side and all R2 leads to the other side. All receiver leads are parallel across the transmitter stator leads--lead for lead.

SYNCHRO CONTROL TRANSFORMERS--HOW IT WORKS

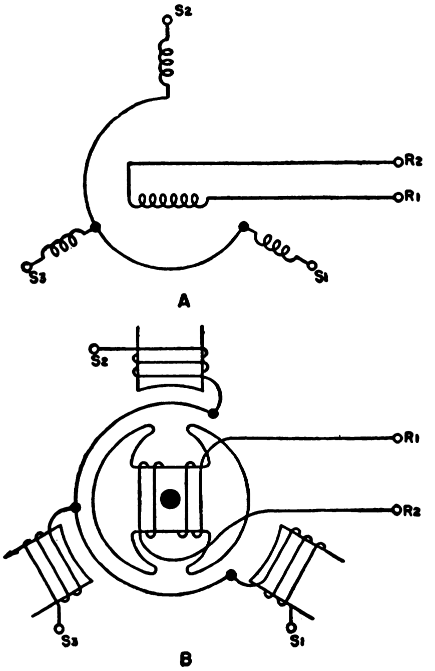
Externally, the CT is like the other synchros. And the brush rigging and slip ring assembly are like other synchros. But the windings are a little different.

In the first place, both the stator and rotor windings have a HIGHER IMPEDANCE than the other synchros. And the transformation ratio between stator and rotor is different--it's about 3 to 2.

The stator winding is the PRIMARY. And like all other synchros, the CT stator has three coils--120 degrees displaced.

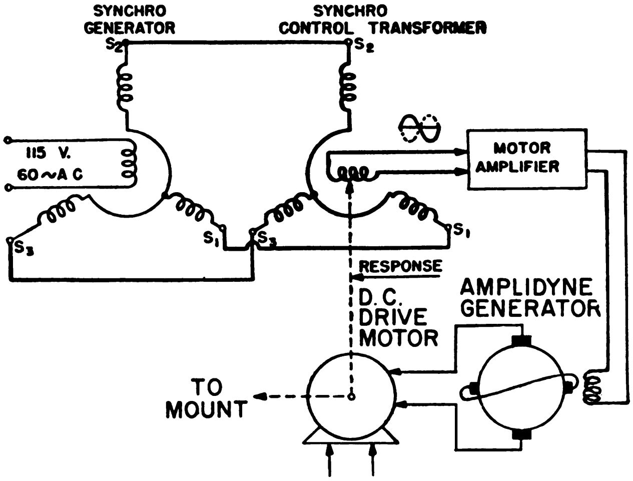
The ROTOR winding is the SECONDARY. And, ELECTRICALLY, the CT rotor is like the generator or motor rotor--it's a single winding connected in series. But the CORE STRUCTURE of the CT rotor is different--you will find that it's round, not bobbin-shaped.

The figure below shows two schematics for a complete CT. Part A is the standard schematic used on prints. Part B is the schematic we will use in this topic.



CT SCHEMATICS

Before we get into the works of a CT, let's see how the CT is used in Power Drive Mk 4, and what it does. Following is a diagram of the Amplidyne type followup as used in Power Drive Mk 4.



The generator is furnishing a ZERO signal to the CT stator. The CT rotor output is ZERO because the CT rotor is DISPLACED exactly 90 degrees from the generator rotor. This means the CT and the generator are in CORRESPONDENCE when their rotors are 90 degrees apart. The ZERO ERROR, or CORRESPONDENCE, condition is shown.

Now, say that the generator rotor is displaced in ONE DIRECTION. The rotors are no longer in correspondence and the CT produces a voltage output. This voltage output is the SOLID sine wave.

Or, say the generator rotor is displaced in the OPPOSITE DIRECTION. The resulting CT output is the BROKEN sine wave. Notice that the PHASE of the CT output REVERSES. In other words, THE PHASE OF THE CT OUTPUT INDICATES THE SIGNAL DIRECTION.

Also, the STRENGTH of the CT voltage output indicates the AMOUNT the two rotors are out-of-correspondence. The CT output voltage is called an ERROR SIGNAL, because the STRENGTH and PHASE of the voltage represents the AMOUNT and DIRECTION that the two rotors are out-of-correspondence with one another.

Now follow the ERROR SIGNAL through. First, the error signal is strengthened in the MOTOR AMPLIFIER. Then the strong signal is used to control the output of the Amplidyne Generator whose output in turn is used to drive the D-C Drive Motor which moves the mount. Mechanical response, geared from the D-C Drive Motor, drives the CT rotor until the CT rotor is again in correspondence with the transmitter rotor. All drive stops when the rotors are in correspondence because, at correspondence, the error signal is zero.

In the following explanation of CT action, five figures have been included to help you understand how a CT works. Remember these points in following the figures through.

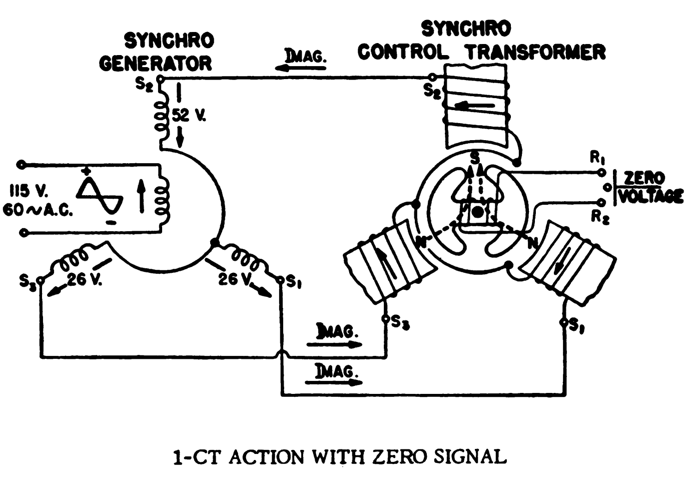
1. A CT gets a signal from a transmitter.
2. The CT output measures the error and the direction of the error.
3. The rotor of a CT is connected to response. This response drive nulls the error signal when the mount is brought into correspondence.

Figure 1 shows the CT action for a ZERO SIGNAL. For a zero signal, the R1 pole of the generator is lined up with the generator S2 coil. And the R1 pole of the CT is displaced 90 degrees, CLOCKWISE, from the CT S2. Both rotors are at ELECTRICAL ZERO.

Notice the generator stator voltages in figure 1. These voltages produce magnetizing currents, Imag, in the CT stator windings. And the magnetizing sets up flux fields in the CT stator. Finally, the CT stator flux cuts the CT rotor and induces a voltage in the rotor windings.

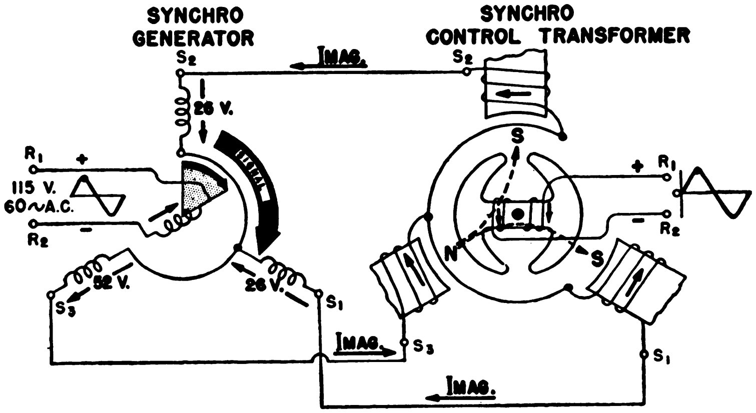
Look at the FLUX FIELDS in the CT. One field is from S1 to S2. Another field is from S3 to S2. And the two fields are of EQUAL STRENGTH because they're produced by equal currents. Equal flux fields INDUCE EQUAL VOLTAGES in the two sides of the rotor. And the equal voltages OPPOSE each other. Result--the net voltage at the leads of the CT rotor is ZERO.

A zero signal at the transmitter rotor produces zero voltage at the CT rotor leads.



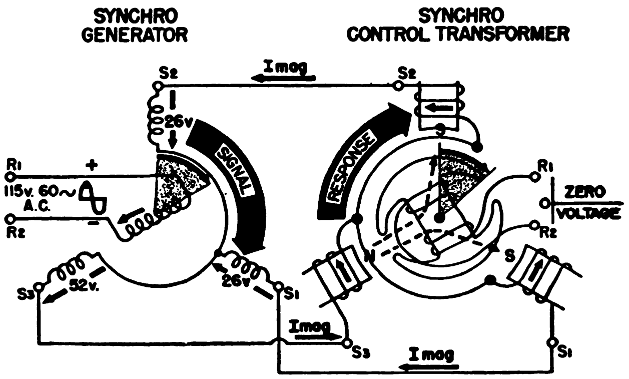
1-CT ACTION WITH ZERO SIGNAL

Figure 2 shows CT action for a clockwise signal of 60 degrees. A voltage is induced in the rotor of the CT by transformer action. The phase of this voltage in the rotor depends on the direction in which the rotor of the generator is turned.



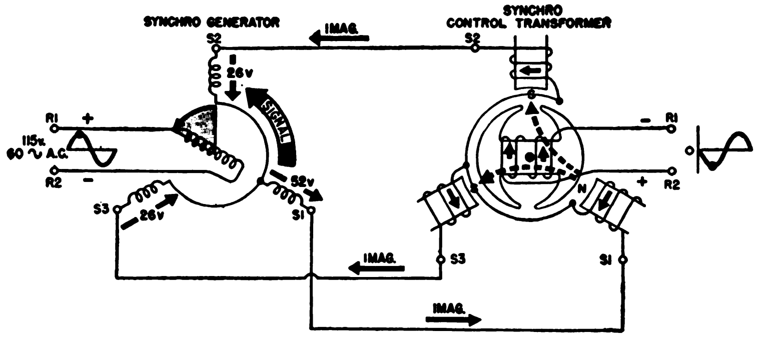
2-CT ACTION WITH CLOCKWISE SIGNAL

Figure 3 shows how response nulls the 60-degree signal.



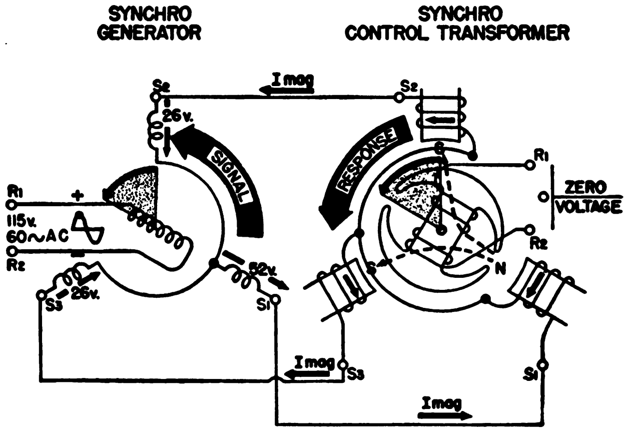
3. NULLING THE CLOCKWISE SIGNAL

Figure 4 shows CT action for a counterclockwise signal of 60 degrees. The magnitude is equal to the preceeding signal but it is opposite in phase.



4. CT ACTION WITH COUNTERCLOCKWISE SIGNAL

Figure 5 shows how the counterclockwise signal of 60 degrees is nulled by response.



5. NULLING THE COUNTERCLOCKWISE SIGNAL

Gun Fire Control System Mk 51, as in many other FC systems, uses a two-speed transmission system. It is so called because two transmitters and two CT's are used to transmit gun orders to the power drive from the gun director.

First, lets take up the transmitters within the director. One synchro generator could be used, but if so, one revolution of the director would cause one revolution of the transmitter. Whenever we moved the director just a slight amount we would get only a very small, if detectable, error signal from the CT. The resultant mount operation would be sluggish, and inaccurate. So another synchro is added to the system and geared in such a way that it will make 36 revolutions for every one revolution the other synchro makes. Now, whenever we move the director a slight amount, one synchro will move slightly, but the other will move a great amount. And if we gear two CT's in the Drive Unit on the mount in the same way, then a sizable error signal may be sent to the amplifier.

Thus we have two-speed train transmission: "coarse" which makes one revolution for each complete revolution of the director, and "fine" which makes 36 revolutions for each complete revolution of the director. The speed ratio of this type transmission is 1:36.

In elevation we have a slightly different arrangement. Because we never elevate in a complete circle, the coarse-speed synchro is geared to make 2 revolutions represent 360 degrees. The fine-speed synchro is geared the same as the train fine-speed synchro and the CT's in the elevation Drive Unit are geared the same as the elevation transmitters in the director.

Using this two-speed transmission system, we never want both coarse and fine synchros in control at the same time. By the action of P1, the synchronizing relay, this is accomplished. Whenever we are out of correspondence more than two degrees, P1 will pick up and short out the fine error signal and allow the coarse error signal to control the mount. If we are within two degrees of correspondence, P1 is caused to drop out and the fine error signal has control of the mount.

ZEROING SYNCHRO UNITS

Zeroing synchros means adjusting them mechanically so that they will work properly in a system or so that they have the same electrical and mechanical starting point.

There are three methods of zeroing synchro motors and generators. The method we will concentrate on is the Voltmeter Method which is the easiest and most accurate method.

The equipment you will need is:

1. Multimeter Model 449 (or any other voltage meter with suitable meter ranges.)
2. Screw driver (6-inch)
3. Jumper lead (12 inches) (2 each)
4. Synchro dial wrench

The procedure for zeroing the synchro transmitters in Gun Director Mk 51 is as follows:

1. Bring the director head to zero in train and elevation and insert the train and elevation lockpins.
2. Remove the access cover on the director pedestal located just behind the power unit.
3. Using voltmeter, make sure that all voltage is secured to director.

Note: The 180-degree check of the coarse elevation transmitter will be made first to make sure we do not zero the unit 180 degrees out.

1. Disconnect leads S1C, S2C, S3C on the terminal strip except those coming from the coarse elevation synchro.
2. On the terminal strip, jumper leads S2C and R1CD together.
3. With scale of at least 200 volts, place the leads of the multimeter across S1C and R2CD.
4. Energize synchro supply.
5. Cast loose the director in elevation and elevate and depress it to determine if minimum voltage (less than 40 volts) is at the locking pin position. Reinsert elevation lock pin.
6. If minimum voltage is at other than the locking pin position, loosen the stator clamps of the coarse synchro and rotate the stator until minimum voltage is read on the multimeter.
7. Secure voltage supply, remove voltmeter and the jumper between S2C and R1CD.

WARNING: By applying full line voltage to the secondary, excessive current will flow in the secondary. Therefore in making this check, circuit should NOT remain energized for more than ONE MINUTE.

Draw the schematic of a synchro generator and the connections to be made when making the 180 degree check of the coarse transmitter.

Once we are sure there is no chance of zeroing the synchro generator 180 degrees out, we can proceed with fine check. The procedure is as follows.

1. Energize the synchro supply to the director.
2. With multimeter set on a low scale, place the leads across terminals S1C and S3C.
3. Unlock director in elevation. Elevate and depress director to see if zero voltage is obtained at the locking pin position. Reinsert elevation lock pin.
4. If minimum voltage is at other than the locking pin position, loosen the stator bolts and rotate stator until zero voltage is read on the multimeter. Retighten stator bolts.
5. Secure synchro supply and reconnect all leads.

Draw the schematic of a synchro generator and the connections to be made when making the fine check of the coarse transmitter.

We have covered in detail the procedure for adjusting the coarse elevation transmitter only. The adjustment procedure for the fine elevation procedure is identical to it, as are the checks and adjustment for train, both coarse and fine. Learn this procedure and you will have no trouble applying it to any synchro transmission system.

Once we have correctly zeroed the transmitters in the director we can proceed to zero the CT's in the Drive Unit. We will cover in detail here the procedure for zeroing both the coarse and the fine CT's.

Coarse Control Transformers

1. Make sure that all voltage is secured.
2. Place the selector lever on the mount in the MANUAL position.
3. Open the stator circuit from the director by disconnecting leads S1A, S2A, and S3A.
4. Jumper leads R2A and S3A together.
5. With scale of at least 200 volts, place the leads of the multimeter across R1A and S1A.
6. Apply 115 volts a-c to S1A and S3A and move mount in MANUAL until minimum voltage is read (less than 50 volts).
7. Leave mount at this position, secure power, and remove jumper and voltmeter.

WARNING: Be careful not to leave the power on long enough to overheat the CT's. If they become unusually warm to the touch, turn the power off and wait until they cool before proceeding with the test.

8. Jumper leads S1A and S3A together.
9. With multimeter set on a low scale, place leads across R1A and R2A.
10. Apply 115 volts a-c to leads S2A and S1A.
11. Rotate gun in MANUAL until zero voltage is read on multimeter.
12. At this time the dials should read zero (in the case of elevation, 2000 minutes). If the dial reading is more than plus or minus 15 minutes off the zero position, loosen the clamp screws and set the dial to exact zero position, tighten clamp screws.
13. Recheck multimeter reading to be sure the gun has not been moved during setting of the dials.
14. Leave mount at this position, secure power, and remove jumper and voltmeter. Draw two schematics of a Control Transformer and on each draw the connections to be made for the approximate zero and final zero position checks.

Fine Control Transformer.

1. Check to make sure that all voltage is secured and selector lever on the mount is in the MANUAL position.
   Open the stator circuit from the director by disconnecting leads S1B, S2B, and S3B.
3. Jumper leads R2B and S3B together.
4. With scale of at least 200 volts, place the lead of the multimeter across R1B and S1B.
5. Apply 115 volts a-c to S1B and S3B.
6. Dials should still read zero and multimeter should indicate approximately the same as it did in step 6 of previous procedure (coarse CT). If the multimeter reads more voltage, loosen the three stator clamps and rotate stator until minimum voltage (less than 50 volts) is obtained.
7. Leave mount at this position, secure power, and remove jumper and multimeter.

WARNING: If CT becomes overheated, secure power and allow it to cool before continuing.

8. Jumper leads S1B and S3B together.
9. With multimeter set on a low scale, place leads across R1B and R2B.
10. Apply 115 volts a-c to leads S2B and S1B
11. Check to make sure dials are on exact zero. At the dial zero position, the multimeter reading should be zero.
12. If multimeter does not read zero, loosen the stator-clamp screws and rotate the stator until zero voltage is read on multimeter when the dials are in their zero position.
13. Reset the stator-clamp screws.
14. Secure power, remove jumper and voltmeter, and replace all disconnected leads.
15. Replace all covers.

Now lets review what we have done. First, we checked and adjusted the synchro generators with respect to the director's zero position. Second, we checked and adjusted the CT's in the Drive Unit with respect to the dials. There is one more adjustment to be done. It is the response adjustment to bring the dials and gun in correspondence. This adjustment will be taken up later in the section on system alignment.

MAINTENANCE OF SYNCHRO UNITS

A synchro is a highly precise instrument and must be handled with the utmost care. Never take one apart. If a synchro unit is working correctly, leave it alone. If you know a synchro is bad, replace it but do it carefully. If you ever replace a synchro, it must be checked and adjusted in the equipment before the equipment is turned on.

SECTION VII

BASIC ELECTRONICS

Topic No.	Topic Title	Sheet
1.	Introduction to Electronics	VII-1-1
2.	Half-Wave Rectifiers	VII-2-1
3.	Full-Wave Rectifiers	VII-3-1
4.	Filter Circuits	VII-4-1
5.	Troubleshooting Power Supplies	VII-5-1
6.	Introduction to Amplifiers	VII-6-1
7.	Triodes	VII-7-1
8.	Triode Amplifier	VII-8-1
9.	Tetrode and Pentodes	VII-9-1
10.	Push-Pull Circuits	VII-10-1

SECTION VII

TOPIC 1

INTRODUCTION TO ELECTRONICS

A. You have learned:	References:
1. The three properties of an electrical circuit	
2. About Resistance, Current, and Voltage in series, parallel, and series-parallel circuits	
3. About power in a series and a parallel circuit	
4. About power rating of equipment	
B. You are learning:	
1. What section VII contains	
2. What electronics means	
3. The purpose and jobs of electronics in Fire Control	
Types of components and types of basic electronic circuits	NavPers 10170, pages 285 to 288

INTRODUCTION TO SECTION VII

Topic 1 gives you an introduction to electronics such as what electronics means, the purpose and jobs of electronics, the types of components, and the basic electronic circuits.
Topic 2 consists of the study of half-wave rectifiers.
Topic 3 consists of the study of full-wave rectifiers.
Topic 4 consists of the study of filter circuits.
Topic 5 consists of the study of trouble-shooting power supplies.
Topic 6 will give you an introduction to amplifiers.
Topic 7 consists of the study of triode vacuum tubes.
Topic 8 consists of the study of the triode amplifier.
Topic 9 consists of the study of tetrode and pentode vacuum tubes.
Topic 10 consists of the study of the push-pull circuit.

WHAT ELECTRONICS MEANS

Electronics is the science of the electron. Since the study of electricity and electronics both involve the use of the concept of electron, the distinction between electricity and electronics may be defined as follows. Electronics is the science which is concerned with the flow of electrons through vacuum or gas-filled tubes. Thus electronics includes the study of any equipment that contains electron tubes.

ELECTRONICS IN FIRE CONTROL

In modern fire control systems, electronic equipment locates the target, measures all the factors that must be considered, calculates how the guns should be aimed, controls the gun-aiming machinery and fires the guns at exactly the right instant. It is the responsibility of the FT rate to properly operate and maintain Navy fire control equipment.

TYPES OF COMPONENTS AND BASIC ELECTRONIC CIRCUITS

There are only six commonly used types of parts used in electronic circuits. They are resistors, capacitors, coils, transformers, switches, and vacuum tubes.

There are only three basic electronic circuits. They are rectifiers, amplifiers, and oscillators.

The basic electronic circuits will be covered in detail in following topics.

SECTION VII

TOPIC 2

HALF-WAVE RECTIFIERS

A. You have learned	References
1. About Resistance, Current, Voltage, and Power in series, parallel, and series parallel circuits	
2. What electronics means	
3. The purpose and jobs of electronics in fire control	
4. The types of components and the types of basic electronic circuits	
B. You are learning	
1. The uses, types, and component parts of power supplies	
2. The uses and types of electron tubes	NavPers 10170, pages 285 to 288
3. The types of electron emission	NavPers 10622-B, pages 291 to 294
4. The uses of characteristics of diode tube	NavPers 10170, pages 288-291 NavPers 10622-B, pages 294 to 296
5. The drode as a half wave rectifier	NavPers 10170, pages 291 to 294 NavPers 10622-B pages 296 to 299
6. The transformer type half wave rectifier	NavPers 10170, pages 299 to 300
7. How the rectifier in the Mk. 4 Power drive operates	

PREVIEW OF POWER SUPPLIES--USES

In electronics, a power supply is a circuit or device that changes the primary power into the kind and amount of a-c or d-c needed by different types of electronic circuits.

TYPES OF POWER SUPPLIES

1. High voltage
2. Low voltage
3. High power
4. Low power
5. Negative
6. Positive

COMPONENT PARTS OF POWER SUPPLIES

1. Transformers
2. Rectifiers
3. Filters
4. Voltage regulators
5. Bleeder resistors

USES AND TYPES OF ELECTRON TUBES

The uses of electron tubes are as rectifiers, amplifiers, and oscillators.

The types of electron tubes are diodes, duodiodes, triodes, twin triodes, tetrodes, pentodes, and multi-element tubes.

TYPES OF ELECTRON EMISSION

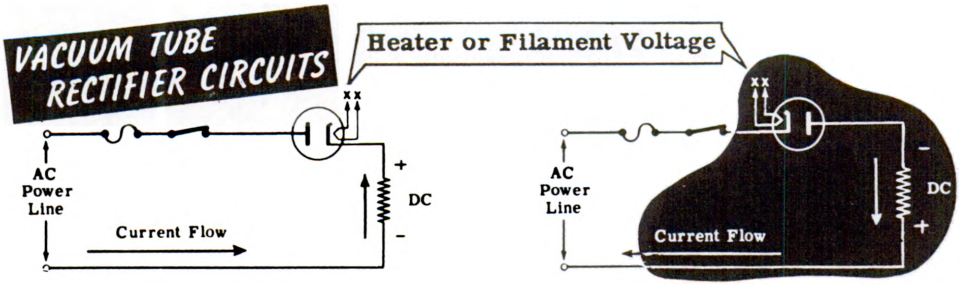
Thermionic Emission is emission of electron due to heat. When a wire is heated, the electrons in their orbits pick up speed. They whirl around the nucleus, their speed ever increasing until they break free from the conductor and shoot into the air around the wire.

Secondary Emission is emission of electrons due to bombardment of a conductor by electrons moving at high speed. Upon impact, the striking electron knocks electrons out of the conductor under bombardment.

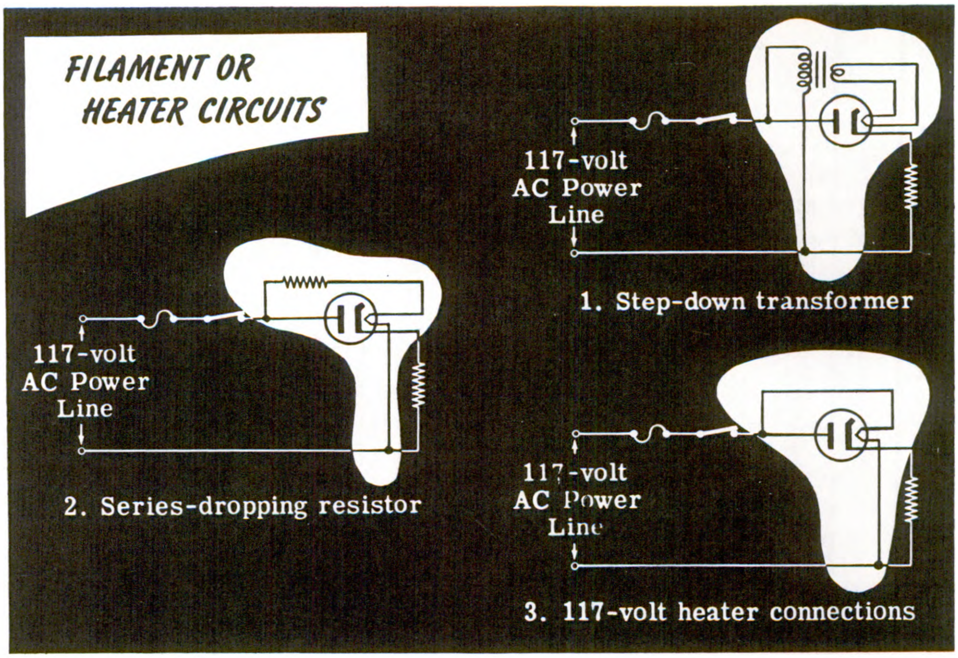
Ionization emission is the emission of electrons from gas. These electrons are emitted when the gas is struck by fast-moving electrons, and the electrons in the gas are then emitted as secondary emission.

THE DIODE AS A HALF-WAVE RECTIFIER

A diode rectifier tube may be used in the half-wave rectifier circuit if there is a voltage source available to supply the filament current required by the rectifier tube. The basic rectifier circuit using a vacuum tube rectifier is illustrated below. If the plate and cathode connections are reversed the polarity of the d-c output voltage is reversed.

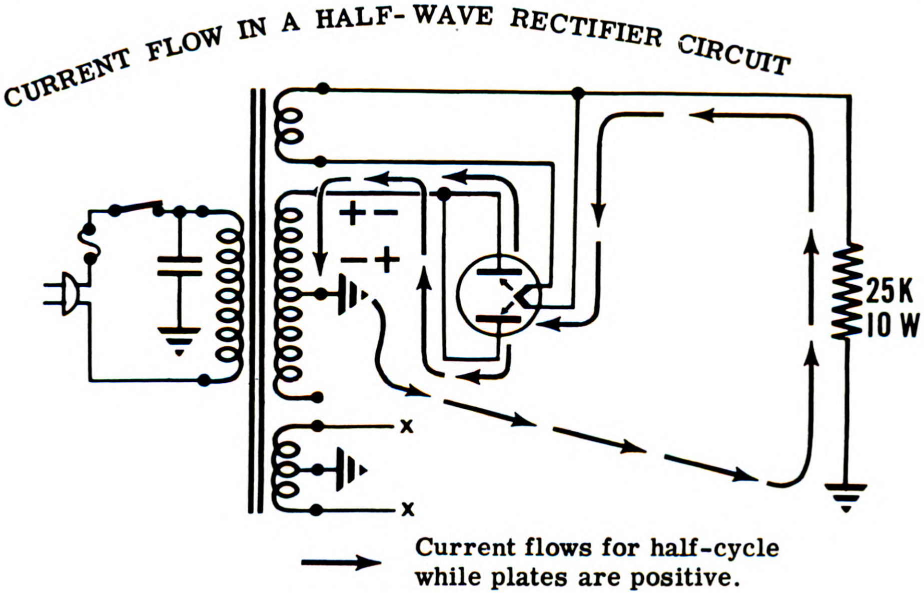


The rectifier tube filament circuit requires an additional source of filament voltage. Rectifier tube filaments are rated in volts and amperes so that the filament must be connected to a voltage source of the rated voltage and current. Filament or heater voltages are normally obtained from a step-down transformer or by using a series resistor to drop the line voltage to the correct value. Tubes having heaters rated at the same current are sometimes connected in series across the a-c power line. Some rectifier tube heaters are rated at 117 volts and may be connected directly across the a-c power line.



TRANSFORMER-TYPE HALF-WAVE RECTIFIER

The basic operation of the half-wave rectifier circuit has been described previously. In the circuit diagram illustrated, the flow of current through the circuit is indicated by arrows. The + and - signs show the reversal in polarity of the transformer secondary voltage for alternate half cycles. The rectifier tube will only conduct from cathode (filament) to plate, and only when the plate is positive with respect to the cathode.


CURRENT FLOW IN A HALF-WAVE RECTIFIER CIRCUIT
+ -
- +
25K
10 W
x
x
Current flows for half-cycle while plates are positive.

JOB SHEET #28

1. The electrons of the ______________________________ form the current through a vacuum tube.
2. The space charge is in the vicinity of the ______________________________.
3. The amount of emission at the cathode depends on the following three things

   ____.
4. The two things necessary before a diode will pass current are ____________________ and ____________________.
5. Thermionic emission is emission of electrons by ______________________________.
6. Ionization is emission of electrons by ____________________.
7. Secondary emission is emission of electrons by ______________________________.
8. Rectifier tube filaments are rated in ____________________ and ______________.
9. Filament or heater voltages are normally obtained from ____________________.
10. The rectifier tube will only conduct from the ______________ to the __________.

SECTION VII

TOPIC 3

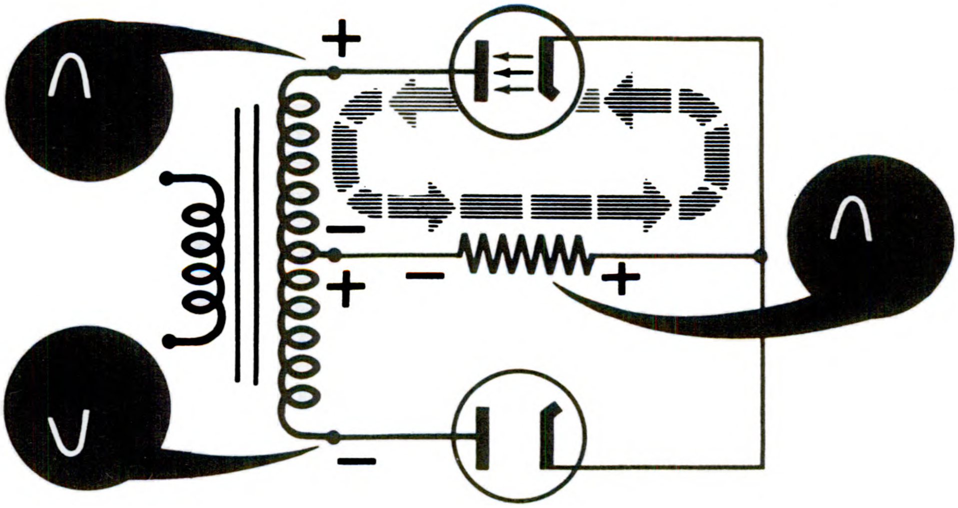
FULL-WAVE RECTIFIERS

	References:
A. You have learned:	
1. The three properties of an electrical circuit.	
2. About the uses, types, and component parts of power supplies.	
3. The types of electron emission.	
4. The diode as a rectifier.	
5. The transformer-type half-wave rectifier.	
B. You are learning:	
1. How the full-wave rectifier works.	OP 821A, pages 61 to 62
2. Characteristics of the full-wave rectifier tube.	NavPers 10170, pages 300 to 304

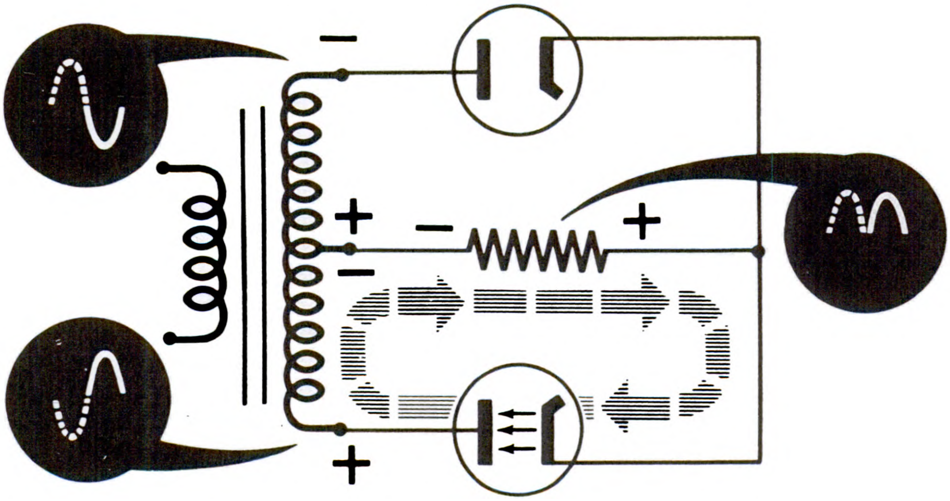
HOW THE FULL-WAVE RECTIFIER WORKS

In a full-wave rectifier circuit, a diode rectifier tube is placed in series with each half of the transformer secondary and the load. Effectively, you have two half-wave rectifiers working into the same load.

On the first half-cycle, the transformer's a-c voltage makes the upper diode rectifier plate positive so that it conducts and, as a result, current flows through the load, causing a pulse of voltage across the load. Notice that while the upper diode conducts, the lower diode plate is negative with respect to its cathode so that it does not conduct.



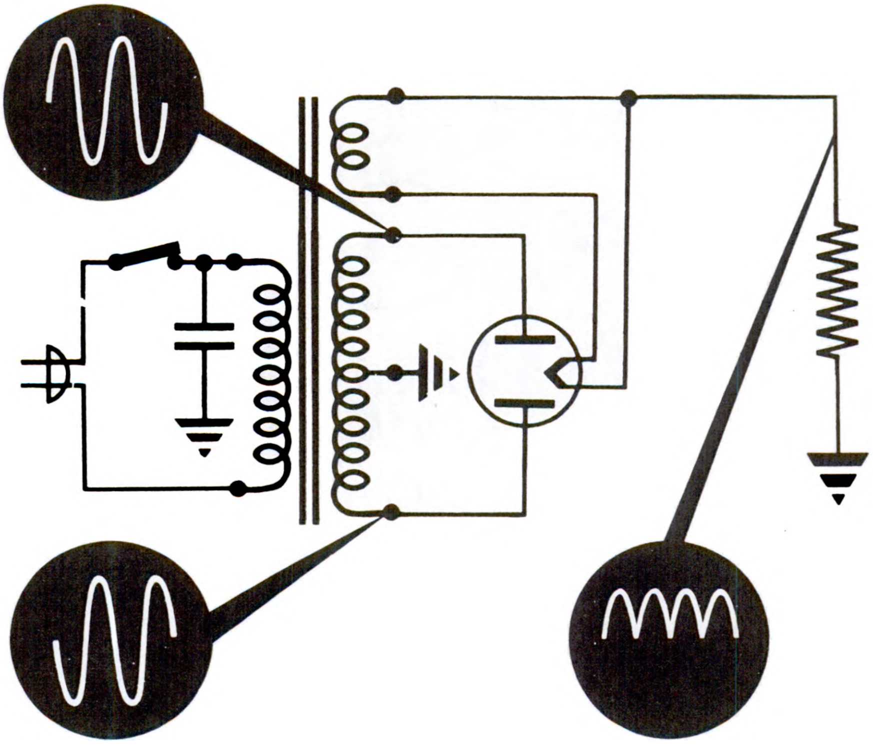
On the second half-cycle, the plate of the upper diode is negative so that it cannot conduct, whereas the plate of the lower diode is positive so that current flows through it and through the load. Since both pulses of current through the load are in the same direction, a pulsating d-c voltage now appears across the load. The full-wave rectifier has changed both halves of the a-c input into a pulsating d-c output.



CHARACTERISTICS OF THE FULL-WAVE RECTIFIER TUBE

The full-wave rectifier is used in place of two half-wave rectifier vacuum tubes.

When a full-wave rectifier is used in a full-wave rectifier circuit, the circuit is most commonly drawn as shown below.



Notice that in this tube there is only one filament which supplies electrons to both plates. During one-half of the a-c input cycle, one plate draws electrons from the filament and, during the other half of the cycle, the other plate draws the electrons. As in any diode, the direction of current flow inside this tube is always from the filament and this current flows first to one plate and then to the other. The load, which is in series with the filament, therefore has pulsating d-c current flowing through it.

JOB SHEET NO. 29

1. The maximum reversed voltage that can be safely applied to a tube without danger of arcing is known as ____.
2. The output of a full-wave rectifier is ____.

SECTION VII

TOPIC 4

FILTER CIRCUITS

A. You have learned:	References:
1. The three properties of an electrical circuit	
2. About the uses, types, and component parts of power supplies	
3. The types of electron emission	
4. The diode as a rectifier	
5. The transformer-type half-wave rectifier	
6. How the full-wave rectifier works and the characteristics of the full-wave rectifier tube	
B. You are learning:	
1. The purpose and types of filters	NavPers 10622-B, pages 306 to 309
2. The purpose of the choke in a filter	NavPers 10170, pages 321 to 322
3. The purpose of the condenser in a filter	NavPers 10170, pages 322 to 323
4. The choke input filter	NavPers 10170, pages 324 to 330
5. The condenser input filter	NavPers 10170, pages 330 to 332
6. The bleeder resistor	
7. The advantages and disadvantages of the choke input filter as compared with the condenser input filter	NavPers 10170, pages 332 to 334

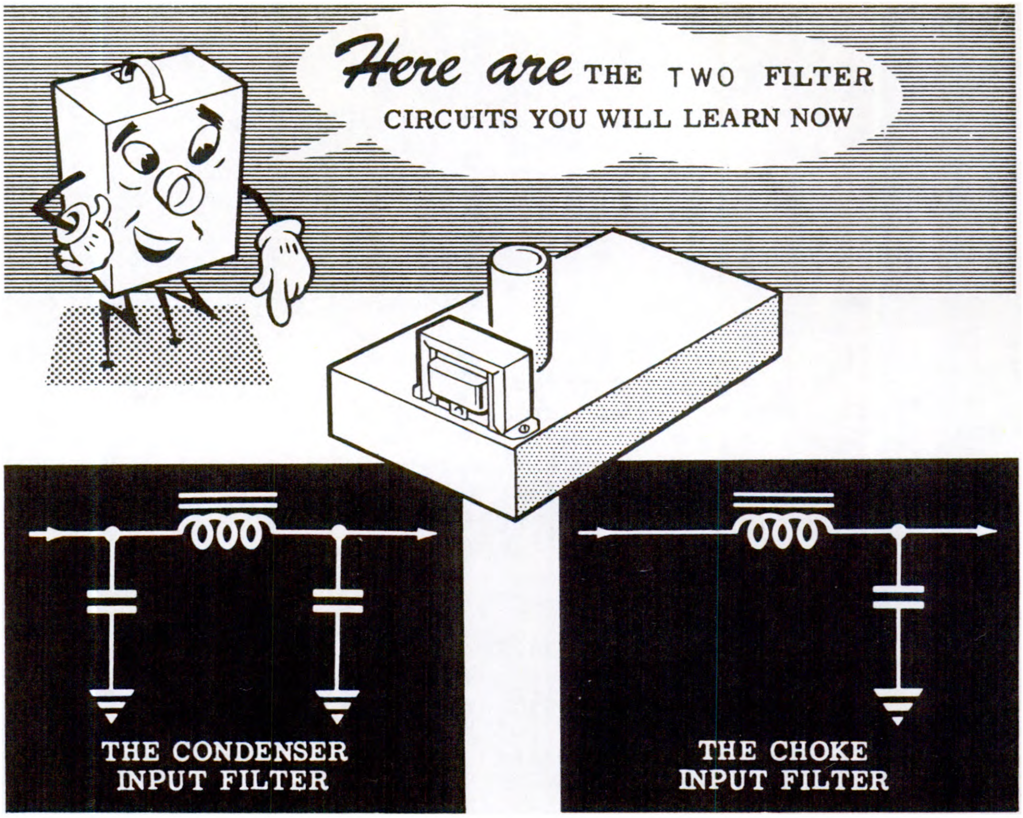
PURPOSE AND TYPES OF FILTER

You already know that there are only two types of rectifier circuits in general use--the full-wave and the half-wave rectifiers--and they both perform the same job of changing a-c into pulsating d-c. There are only three types of filter circuits that are in general use. All these filter circuits have one thing in common--they remove the ripple from the pulsating d-c output of the rectifier.

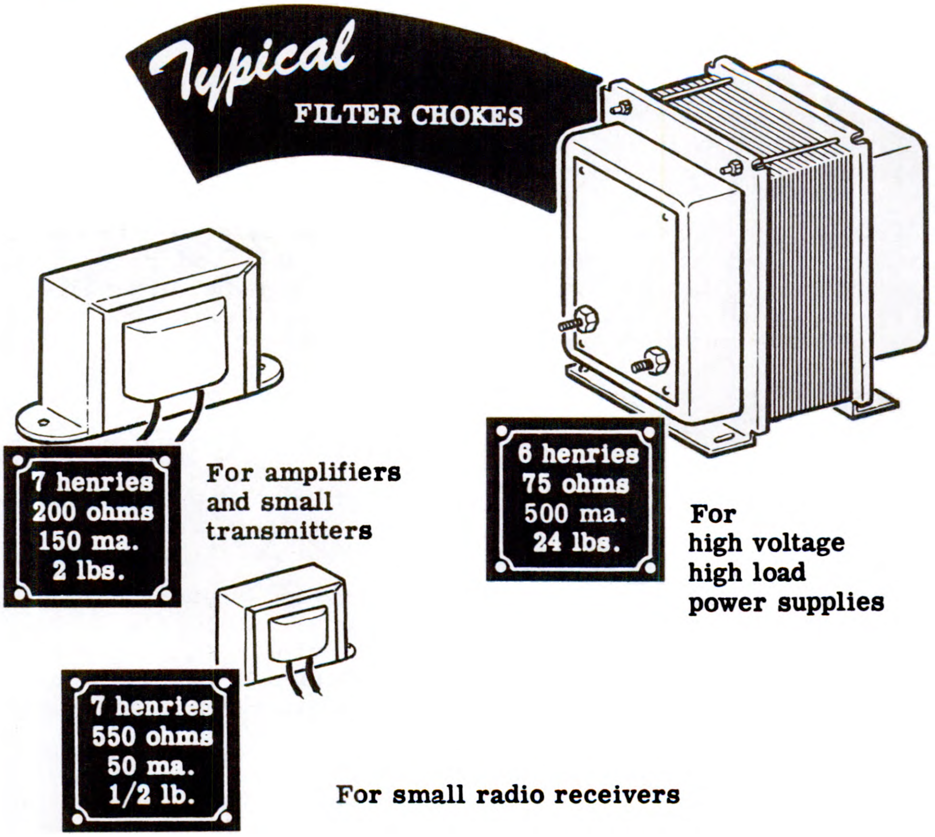
PURPOSE OF THE CHOKE IN A FILTER

The purpose of a filter choke is to furnish a high impedance to a-c ripple voltage and a low resistance to d-c current. A choke consists of many turns of copper wire wound around a laminated iron core. The total impedance of the choke depends upon the number or turns of wire and the size, shape, and material of the core. The d-c resistance of the choke depends upon the total length of wire used and the diameter of the wire.

By increasing the number of turns of wire and by increasing the size of the core, you can raise the impedance; but this also increases the size and the weight of the choke. In addition, the increased length of wire through which the current must flow causes the d-c resistance to increase. The only way to decrease d-c resistance is either to decrease the number of turns (which lowers the impedance) or to increase the diameter of the wire (which increases the weight).


Here are THE TWO FILTER CIRCUITS YOU WILL LEARN NOW
THE CONDENSER INPUT FILTER
THE CHOKE INPUT FILTER

Typical FILTER CHOKES


7 henries
200 ohms
150 ma.
2 lbs.
6 henries
75 ohms
500 ma.
24 lbs.
7 henries
550 ohms
50 ma.
1/2 lb.

For amplifiers and small transmitters

For high voltage high load power supplies

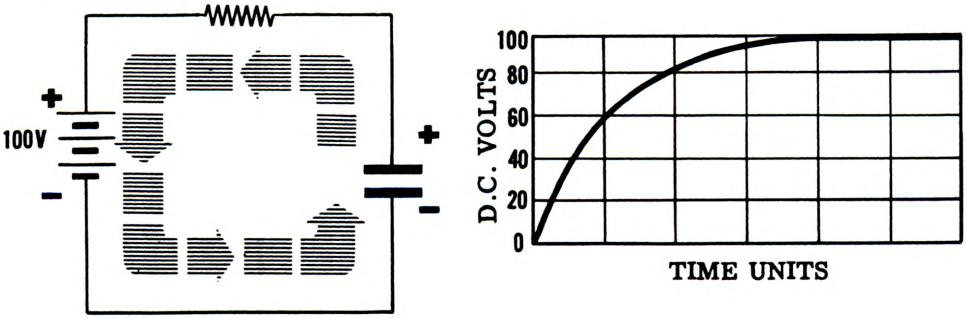
For small radio receivers

Every type of choke manufactured is a compromise of size, weight, a-c impedance and d-c resistance requirements. Because requirements differ according to the equipment, many different sizes of chokes are made. Chokes are rated by the amount of inductance, the d-c resistance and the maximum amount of current flow.

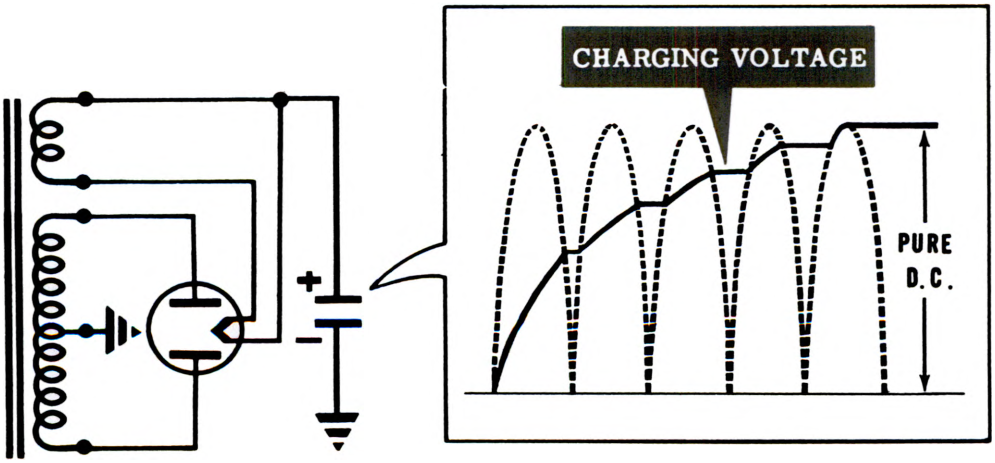
PURPOSE OF A CONDENSER IN A FILTER

If you remove the load resistor from the output of the rectifier and replace the resistor with a large condenser, pure d-c will appear across the condenser. When you find out why this takes place, you will see how this effect can be used in filter circuits.

You know that when a condenser is placed across a battery, it charges up to the battery voltage if it is given enough time.



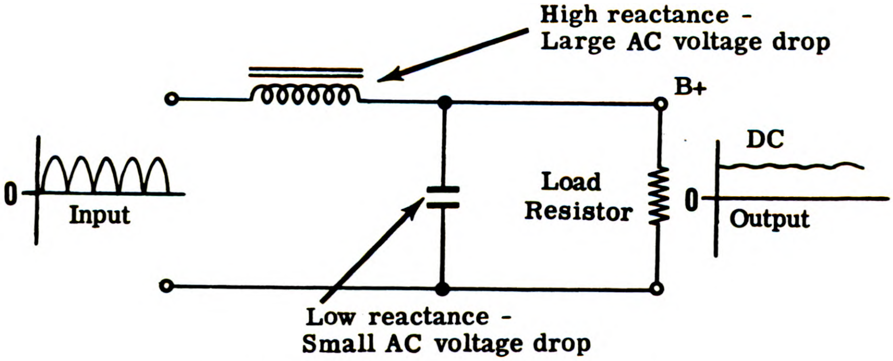
The same is true when a condenser is placed across the output of a rectifier. The rectifier starts charging up the condenser every time it conducts. If the condenser does not have time to charge up to the peak of the pulsating d-c wave on the first half-cycle, it will do so during the next few half-cycles. After a few cycles have passed, there will be pure d-c across the condenser. Because current can flow in only one direction through the rectifier, the condenser will not discharge between the peaks of the pulsating d-c voltage. What has been the effect of placing the condenser across the output of the rectifier? By charging up, the condenser has filtered out the ripple in the pulsating d-c, leaving pure d-c.



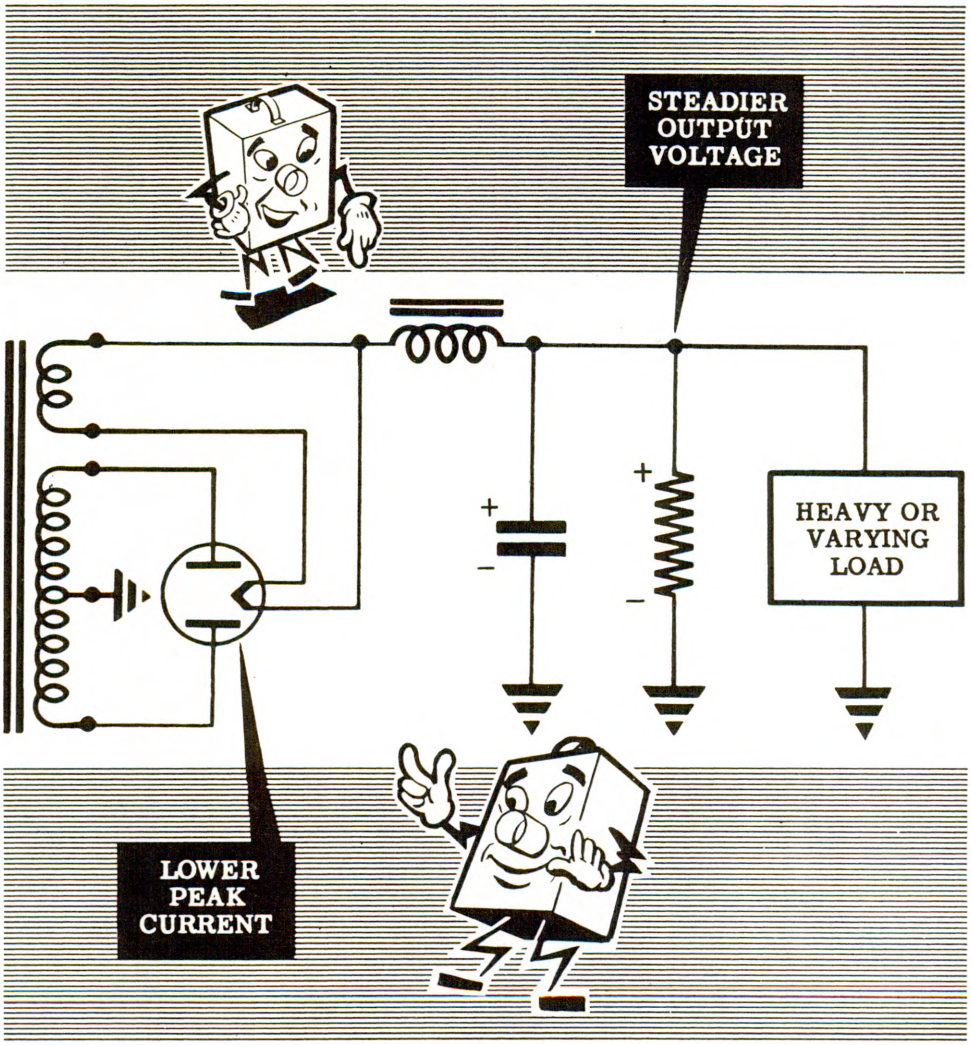
ACTION OF THE FILTER CONDENSER

CHOKE INPUT FILTER

The single-section choke input filter consists of a filter choke in series with the power supply load and a filter condenser across the load. The d-c component of the rectifier output appears across the load. Most of the a-c component appears across the high inductive reactance of the choke. Only a small amount of a-c appears across the output filter condenser because of its low reactance. Since the load is in parallel with the output filter condenser, very little ripple appears across the load.



You will see that the single-section choke input filter does just a little better job of filtering than the condenser alone. The voltage output of the choke input filter is lower than



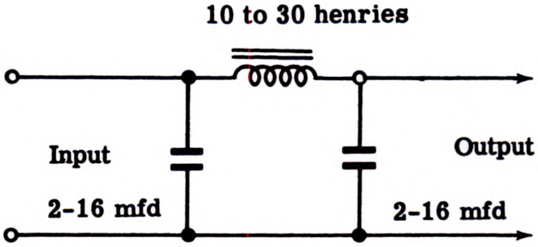
the voltage output of the condenser alone. This is because the choke builds up a back emf which cancels a part of the voltage coming out of the rectifier. An important feature of the choke input filter is that it limits the peak current flowing through the rectifier tube and, as a result, there is less strain on the tube. The choke input filter also has the characteristics of holding the output voltage quite constant despite load variations. Because of these last two characteristics, choke input filters are used most commonly in power supplies which are subjected to heavy or varying loads. The results of using this type of filter for such loads are a more stable output voltage from the power supply and longer life of the rectifier tube.

CONDENSER INPUT FILTER

A single-section condenser input filter consists of a filter condenser connected across the input terminals of a single-section choke input filter. Because of the shape of the circuit diagram, filter circuits of this type are sometimes called "π type" filters.

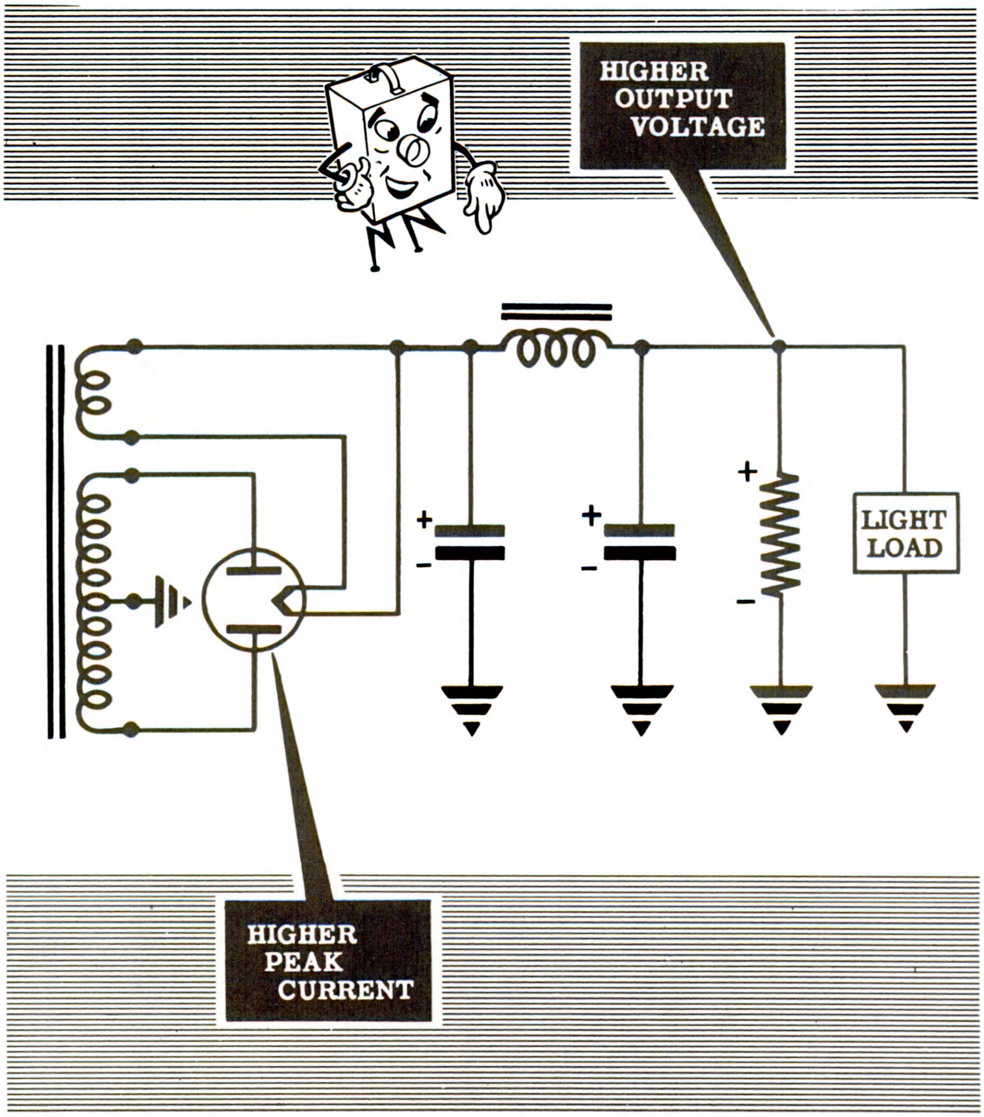
Large values of inductance and capacitance are used in condenser input filters so that they are often called "brute-force" filters. Inductance values of from 10 to 30 henries and capacitance values of from 2 to 16 microfarads are commonly used.

SINGLE-SECTION
CONDENSER
INPUT
Filter..... Circuit



By comparing these waveforms and voltages with those of the preceding filter circuits, you can see that the condenser input filter does a better job of filtering than any of the others. The voltage output of this filter is larger than it was for the choke input filter because of the charging and discharging action of the input condenser.

However, unlike the choke input filter, this circuit draws large peaks of current from the rectifier tube. The voltage regulation is not as good as it is for a choke input filter. The condenser input filter, very often called a "brute-force" filter, is the most widely used filter circuit for applications where the required amount of d-c power is small.



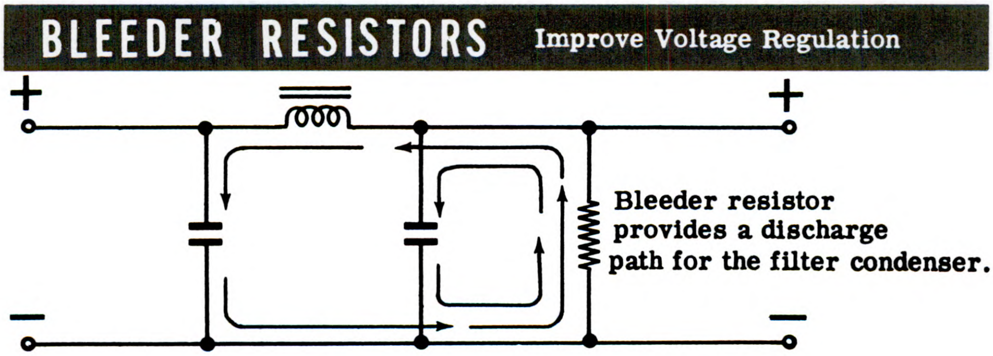
BLEEDING RESISTOR

If the load is entirely removed from a power supply, the voltage rises to a value much higher than normal. With no-load current there is no d-c voltage drop in the circuit and no discharge path for the filter condensers, resulting in a build-up in voltage across the filter condensers to a value approximately equal to the peak a-c voltage applied to the rectifier tube.

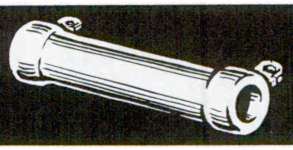
To prevent soaring of the voltage at no-load, resistors are often connected across the output terminals of power supplies. These resistors, called "bleeder resistors," provide a discharge path for the filter condensers and also serve as a fixed load to bleed off a constant value of current. The bleeder resistor usually draws about 10 percent of the total rated current output of the power supply.

Since a bleeder resistor prevents sharp increases in voltage output under light or no-load conditions, it improves the power supply voltage regulation and tends to maintain the output voltage at a constant value regardless of load. This method of voltage regulation is sufficient for most power supply applications but in many cases better voltage regulation is required.

Bleeder resistors dissipate a relatively large amount of power as heat and should be mounted in a well-ventilated position. The resistance value and power rating of the bleeder resistor depend on the maximum voltage and current ratings of the power supply. For example, if a power supply is rated at 300 volts and can supply 100 miliamperes, the bleeder current should be about 10 milliamperes and the voltage across the bleeder, 300 volts. The bleeder resistance (30,000 ohms) is found by dividing the voltage (300 volts) by the bleeder current (.01 ampere). The power dissipated is equal to the voltage multiplied by the bleeder current. (300 x .01 = 3 watts). The wattage rating of a resistor should be higher than the power dissipated so that a 30 k, 10-watt resistor is used as a bleeder.


BLEEDER RESISTORS Improve Voltage Regulation

Bleeder resistor provides a discharge path for the filter condenser.

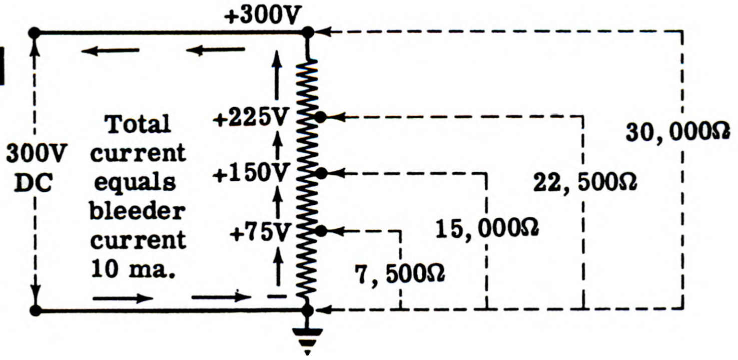

Bleeder resistors provide a continous load for the power supply.

Bleeder resistors are sometimes tapped to provide one or more voltages lower than the maximum voltage of the power supply. The bleeder may consist of several resistors connected in series across a source of voltage with various voltages available at the resistor junctions.

When a bleeder is connected directly across the power supply output, the voltage at various points along the bleeder is exactly proportional to the resistance at that point, provided no current is drawn from any of the taps. For example, if a 30,000-ohm resistor tapped at 7,500 ohms, 15,000 ohms and 22,500 ohms, is connected across the output of a 300-volt power supply, the voltage divides proportionately. At the 15,000-ohm tap, the voltage is one-half of the total or 150 volts, at the 7,500-ohm tap it is one-fourth of the total or 75 volts and at the 22,500-ohm tap it is three-fourths of the total or 225 volts. The bleeder current through the resistor is 10 milliamperes.

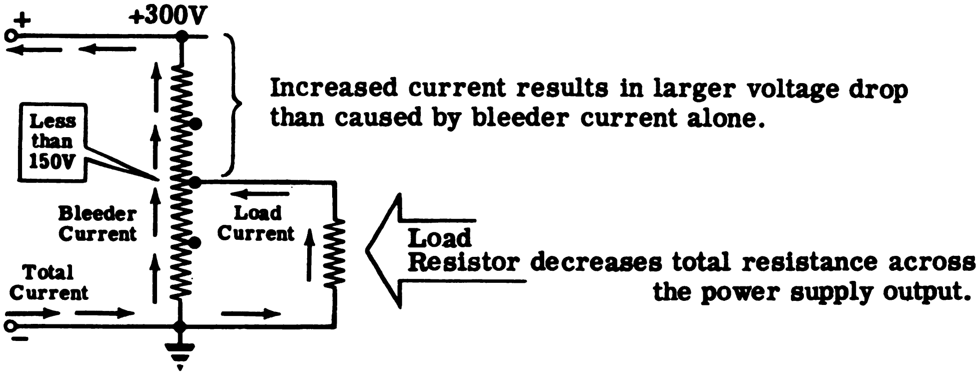
VOLTAGE DROPS

ACROSS A TAPPED BLEEDER RESISTOR



The voltages available at the voltage divider taps depend on the current drawn from each tap and are affected by changes in current supplied by any of the voltage taps. When a load is connected to any of the taps its resistance is in parallel with a portion of the voltage divider. This forms a series-parallel circuit and reduces the total resistance across the circuit, resulting in an increase in current drawn from the power supply. The voltage drop in the series part of the voltage divider circuit increases due to the increased current, and the voltage drop and bleeder current for the parallel part of the voltage divider are decreased.

TAPPED BLEEDER RESISTOR WITH A LOAD CONNECTED



Increased current results in larger voltage drop than caused by bleeder current alone.

Load Resistor decreases total resistance across the power supply output.

ADVANTAGES AND DISADVANTAGES OF THE CHOKE INPUT FILTER AS COMPARED WITH THE CONDENSER INPUT FILTER

The choke input filter has good voltage regulation. But its output voltage is only the average value of the pulsating d-c input. Good voltage regulation makes the choke input filter the best for variable loads that demand steady voltage. But the choke input filter can deliver only the average value of the pulsating d-c input. The condenser input filter has a poor voltage regulation. But it has the advantage of a high output voltage. The output is nearly the peak value of the d-c input. That makes the condenser input filter the best for steady loads that demand a high voltage.

JOB SHEET NUMBER 30

1. Filters do the job of ______________________________ pulsating d-c.
2. The voltage of self-induction produced by the choke coil __________________________________ any changes of current.
3. The choke is connected in ____________________________with the load.
4. The condenser is connected in ________________________ with the load.
5. The choke input filter tends to smooth the pulsating d-c out at its ______________________ value.
6. The condenser input filter tends to smooth the pulsating d-c out at its ________________________value.

SECTION VII

TOPIC 5

TROUBLESHOOTING POWER SUPPLIES

A. You have learned: References

1. The uses, types, and component parts of power supplies
2. How the half-wave and full-wave rectifiers work
3. Purpose, types, and advantages of various types of filters
4. Purpose and operation of the bleeder resistor

B. You are learning:

1. Methods of troubleshooting
2. Component troubles
3. Use and operation of the C.R.O. and tube tester
4. Examples of troubleshooting

C. You will acquire skill in:

1. Troubleshooting power supplies

METHODS OF TROUBLESHOOTING

Visual Checking

The importance of this step should not be underestimated--troubleshooters find many defects simply by looking and seeing them right away. When you are working with a simulated defect (one that you yourself have put in), the idea is to ignore the visible defect and try to find it by signal tracing. However, when you are working with a real trouble or one that is put in as a problem, you can often find it by inspection.

Visual checking does not take long--in about two minutes you should be able to see the trouble if it is the kind that can be seen. Learn the procedure which follows--you will be using it very often. It is good not only for power supplies but for any type of electronic gear.

1. Before you plug in the equipment, look for:

   a. Loose tubes--A tube that is not properly seated in its socket may not be making proper contact with the rest of the circuit. It may very well be a source of present or future trouble. Push the tube completely into place.

   b. Shorts--Any terminal or connection that is close to the chassis or to any other terminal should be examined for the possibility of a short. A short in any part of the power supply can cause considerable damage. Look for and remove any stray drops of solder, bits of wire, nuts or screws. It sometimes helps to shake the chassis and listen for any tell-tale rattle. Remember to correct any condition that may cause a short circuit. If it isn't causing trouble now, it may begin ''acting up'' in the future.

During the process of visual checking and signal tracing, you may find a terminal which the ohmmeter indicates is shorted to ground, but the cause of the short may not be immediately obvious. In order to locate the component causing the short, it is necessary to disconnect the parts one by one from the shorted terminal. Unsolder each suspected part from the terminal. As you disconnect each component, check the resistance from the terminal to ground. When the short disappears from the terminal, you have just removed the shorted component. Check the resistance from the detached end of the component to ground. Try to find the reason for the short. If it cannot be corrected because of a defect in the part, replace the part.

c. Discolored or leaking transformer--This is a sure sign that there is a short somewhere. Locate it. If the equipment has a fuse, find out why the fuse didn't blow out; too large a size may be installed or there may be a short across the fuse holder.

d. Loose, broken, or corroded connections--Any connection that is not in good condition is a trouble spot. If it is not causing your present trouble, it will probably cause trouble in the future. Fix it.

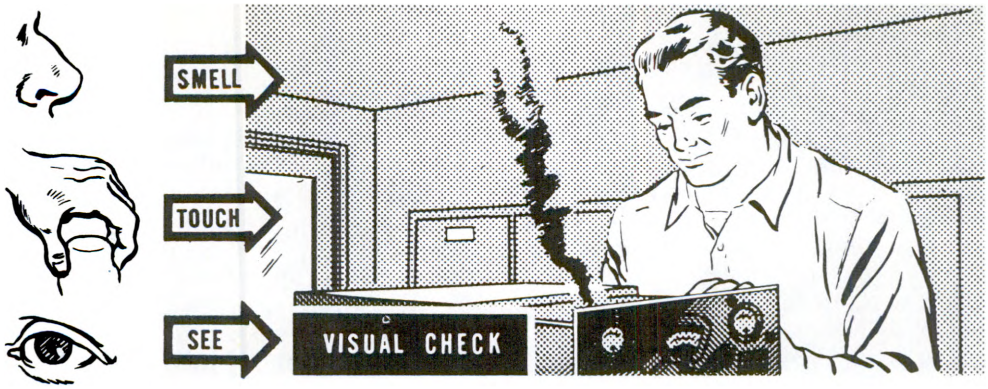
e. Damaged resistors or condensers--A resistor that is discolored or charred has been subjected to an overload. An electrolytic condenser will show a whitish deposit at the seal around the terminals. Check for a short whenever you notice a damaged resistor or condenser. If there is no short, the trouble may be that the power supply has been overloaded in some way. Make a note to replace the part after signal tracing. There is no point in risking a new part until you have located the cause of the trouble.

2. Plug in the power supply and look for:

a. Smoking parts--If any part smokes or you hear any sound of boiling or sputtering, pull out the plug immediately. There is a short circuit somewhere that you have missed in your first inspection. Locate it with your ohmmeter--beginning in the neighborhood of the smoking part.

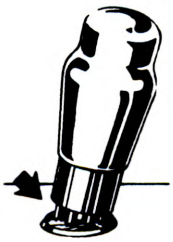
b. Cold tubes--Touch all the tubes on the equipment after you have allowed about two minutes for warming up. If a tube is cold, it is either burned out or there is a break in the heater connections and the tube is not receiving proper heater voltage. Remove the tube and connect your ohmmeter across the heater terminals to see whether or not the filament is open (reads almost infinite resistance). If the filament reads open, it is burned out--replace it with a good tube. If the filament reads a low resistance, it is all right--replace the tube and use an a-c voltmeter to find the break in the path of the heater voltage from the transformer.

c. Sparking--Tap or shake the chassis. If you see or hear sparking, you have located a loose connection or a short. Check and repair. If you have located and repaired any of the defects listed under visual checking, make a note of what you found and what you did to correct it. It is quite probable that you have found the trouble. Take nothing for granted--you must prove to yourself that

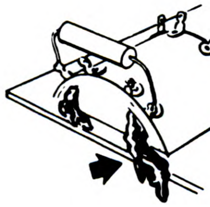


the equipment is operating properly and that there are no other troubles. Follow the procedure for signal tracing described in the following paragraphs.

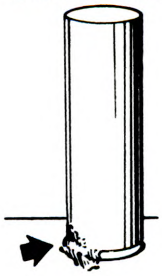
LOOSE TUBE

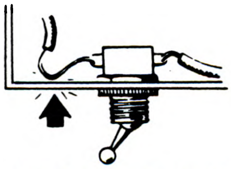


LEAKING TRANSFORMER

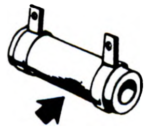


LEAKING CONDENSER

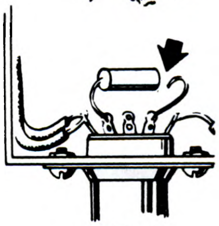




SHORT CIRCUIT



DISCOLORED RESISTOR



OPEN CONNECTION

If you have found none of the defects listed under visual checking, go ahead with the signal-tracing procedure. Your trouble is probably of such nature that it cannot be seen directly with your eye--it must be seen through the eye of the oscilloscope.

Signal Tracing

Tracing the a-c signal through the equipment is the most rapid method of locating a trouble that cannot be found by visual checking, and it also serves as a check on any repairs you may have made. The idea is to trace the a-c voltage through the transformer, see it change to pulsating d-c at the rectifier tube filament, then see the pulsations smoothed out by the filter. The point where the signal stops or becomes distorted from what it should be is the place to look for the trouble.

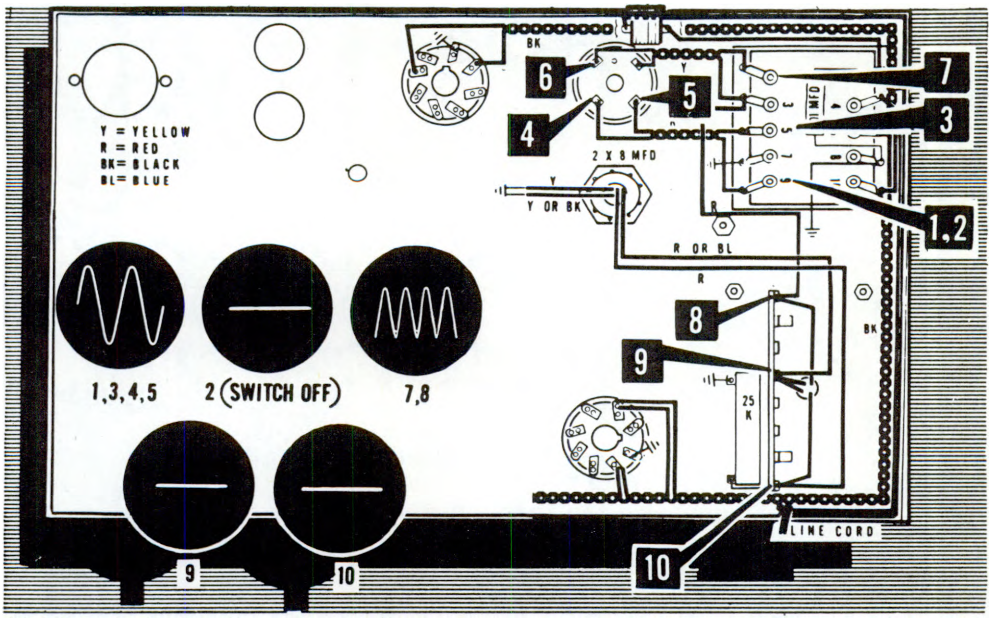
Before you begin signal tracing, it would be a good idea to measure the d-c voltage across the bleeder resistor (25,000 ohms). The d-c output voltage should be in the neighborhood of 340 volts. If you have no d-c output voltage, you will be looking for an open or a short in your signal tracing. If you have a low d-c voltage you will be looking for a defective part, and you will have to keep your eyes open for the place where the signal becomes distorted.

Signal tracing is done by observing the waveform at the input and output of each part of a circuit. It is the method used to localize troubles in circuits.

Let's review what each part of a good power supply does to the signal. The a-c voltage is brought in from the power line by means of the line cord. This a-c voltage is connected to the primary of the transformer through the ON-OFF switch. At the secondary winding of the transformer (Points 1 and 3), the 'scope shows you a picture of the stepped-up a-c voltage developed across each half of the secondary winding--the picture is that of a complete sine wave. Each of the two stepped-up voltages is connected between ground and one of the two plates of the rectifier tube. At the two rectifier plates (Points 4 and 5), there is still no change in the shape of the stepped-up a-c voltage--the 'scope picture still shows a complete sine wave.

However, when you look at the 'scope picture for Point 7 (the voltage at the rectifier heater), you see the wave shape for pulsating direct current. This pulsating d-c is fed through the first choke and filter condenser, which removes a large part of the ripple or "hum," as shown by the picture for Point 9 with the 'scope vertical gain control turned to maximum. Finally, the d-c voltage is fed through the second choke and filter condenser, which removes nearly all of the remaining hum. See the picture for Point 10, which shows almost no visible hum with the 'scope vertical gain control turned all the way up. You now have almost pure d-c.

No matter what power supplies you may run into in the future, they all do the same thing--they change a-c voltage into d-c voltage.



Advantages of signal tracing

1. The point-to-point system of voltage and resistance measurement is no longer practical with present-day electronic equipment because:
   a. The number of points to be tested has increased tremendously.
   b. Operating voltages and resistance may be normal and yet the equipment may be inoperative because:

(1) Misalignment of tuned circuits and coupling circuits (due to age, moisture, vibration, etc.) ordinarily have no effect on operating voltages and resistance.

(2) Many types of automatic control voltages (automatic frequency control, automatic volume control, automatic noise suppression, etc.) and diode detection depend upon a proper signal condition for their operation. These conditions are not apparent in static testing.

(3) Defective tubes may have proper voltages and may be "accepted" by a tube tester, but do not function in the circuit.

2. Signal tracing has the following advantages:

a. The number of points to be tested is cut down tremendously since an entire section of the equipment containing dozens or even hundreds of static checking points (entire audio amplifier, entire I. F. amplifier, entire sawtooth generator, etc.) may be tested at once by inserting a signal at the input and observing the signal at the output. As a result, the general area of trouble may be identified almost immediately for further testing.

b. Misalignment of tuned circuits and coupling circuits can be recognized by examining for lack of signal or distorted signal.

c. Tubes that are functionally defective may be rapidly located by comparing the input and output.

d. Automatic control voltages and diode detection may be observed under actual or simulated operating conditions.

e. Due to the fact that the trouble may be rapidly localized, the troubleshooter can devote the major part of his efforts to effective work in finding the exact part which is defective.

f. Once trained in the method of signal tracing, the troubleshooter can effectively test any type of equipment with which he is familiar even though he has had no experience with that particular model.

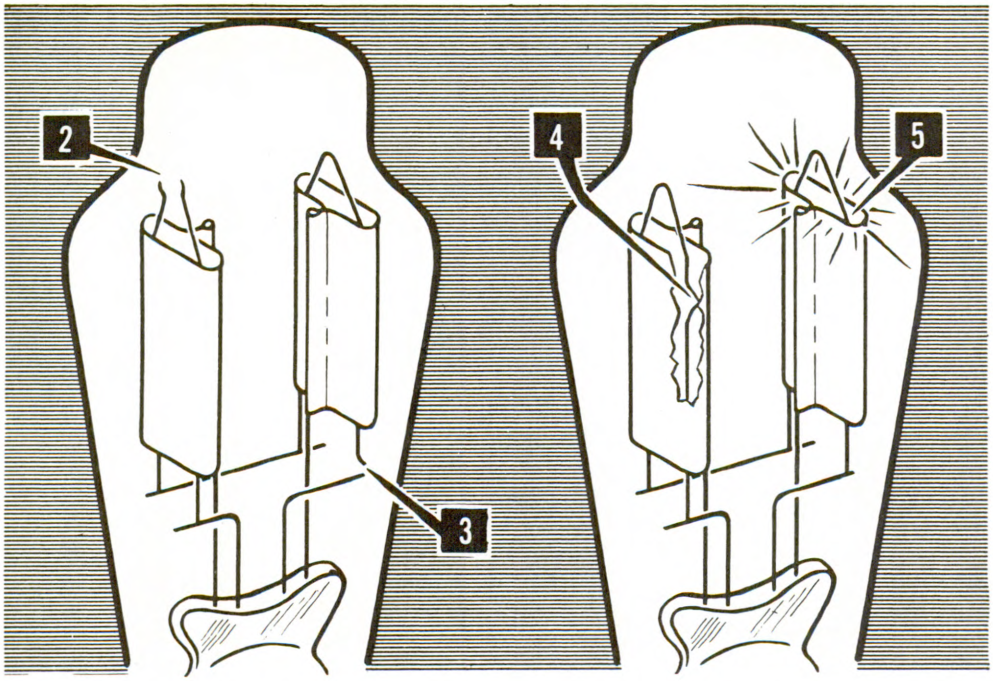
Conclusion

The advantages of signal tracing are its speed, its universal application, and its positive identification. It is a functional test of a circuit under conditions of actual use.

COMPONENT TROUBLES

Tube troubles

Of course, the symptoms of tube trouble will vary with every type of circuit and each type of tube. However, the troubles that can happen to a tube are common to every tube. Here are the five possible tube troubles which you must keep in mind. The meaning of each trouble will be clear by the time you end the study of vacuum tubes, even though you may not quite understand it now.



1. The filament, after long service, may be unable to emit as many electrons as are required for proper operations.

2. The filament may burn out.

3. A tube element--the plate, for instance--may break its connection with the tube base pin.

4. Two elements, such as filament and plate, may short together.

5. The tube may become gassy.

The symptoms you will come across in signal tracing will be many and varied. You will need to combine your ''know-how'' of the circuit and your knowledge of these five possible tube troubles to determine if the tube could in some way be causing the symptoms. If the tube is suspected of causing trouble, then you will need to try another tube in its place or check it on a tube tester. But remember, the final check of whether or not the old tube was bad is whether or not the equipment works properly when a good tube is put in its place. Therefore, putting in a good tube and trying out the equipment is the best check.

Transformer and choke troubles

As you already know, the transformer and choke are quite similar in construction. Therefore, it is no coincidence that the basic troubles that can happen to them are the same.

1. A winding can open up.

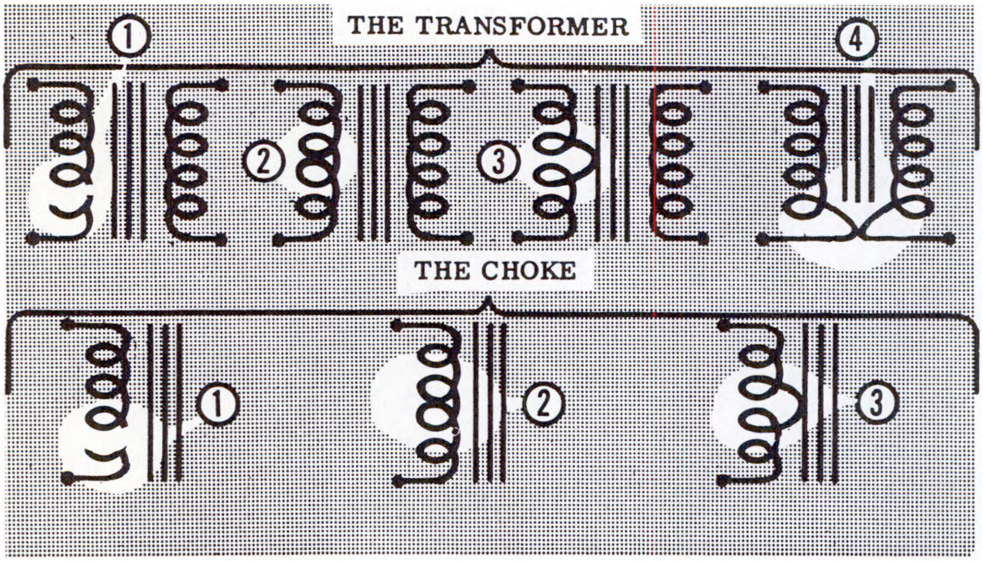
2. Two or more turns of one winding can short together.

3. A winding can short to the casing which is usually grounded.

4. Two windings can short together. This trouble is, of course, possible only in transformers.

As with the tube, the symptoms in the circuit of these troubles will vary with the type of circuit. However, when you have once decided that one of these four possible troubles could be causing the symptoms, there are definite steps to take. If you surmise that there is an open winding or windings shorted together or to ground, an ohmmeter continuity check will turn up the trouble. If the turns of a winding are shorted together, you may not be able to detect a difference in winding resistance. Therefore, you would need to connect a good transformer in place of the old one and see if the symptoms were eliminated, but keep this in mind; transformers are difficult to replace. Make absolutely sure before changing the transformer, that the trouble is not elsewhere in the circuit.

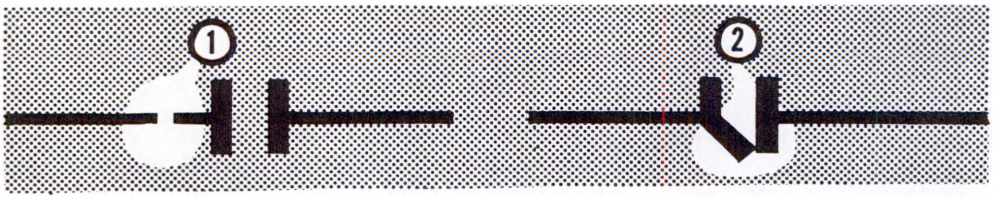
Occasionally, the shorts will not appear except when the operating voltages are applied to the transformer. In this case you might find the trouble with a megger, an instrument which applies a high voltage as it reads resistance. Your instructor will tell you more about this.



CONDENSER AND RESISTOR TROUBLES

Just two things can happen to a condenser:

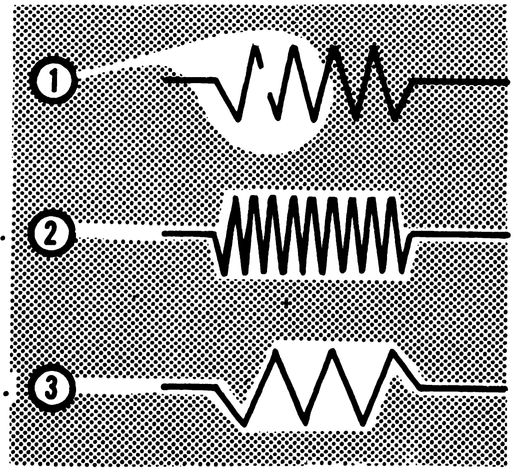
1. It may open up--removing the condenser completely from the circuit.
2. It may develop an internal short circuit. This means that it begins to pass current as though it were a resistor or a direct short.



You may check a condenser, suspected of being open, by disconnecting it from the circuit and checking it with a capacity meter. You can check one, suspected of being leaky, with an ohmmeter--if it reads less than 500K, it definitely is bad. However, condenser troubles are difficult to find since they may appear intermittently or only under operating voltages. Therefore, the best check of a doubtful condenser is to replace it with one known to be good. If this restores proper operation, the fault was in the condenser.

Resistor troubles are the simplest of the lot but, like the rest, you must keep them in mind all the time.

1. A resistor can open up.
2. A resistor can increase in value.
3. A resistor can decrease in value.



You know already how to check possible resistor troubles. Just use an ohmmeter after making sure that there is no parallel circuit connected across the resistor you wish to measure. When you are in doubt or are sure that there is a parallel circuit, disconnect one end of the resistor before measuring it. The ohmmeter check will usually be adequate. However, never forget that occasionally intermittent troubles may develop in resistors as well as in any other electronic part, so that the final proof that a resistor is bad is when another resistor in its place makes the equipment operate satisfactorily.

USE AND OPERATION OF THE C.R.O. AND TUBE TESTER

This topic will be explained by the instructor because there are too many types of C.R.O.'s and tube testers to elaborate on at this time.

EXAMPLES OF TROUBLESHOOTING

Now that you know what to do, let's go through some typical troubleshooting problems. Pay careful attention, because you will carry out the same procedures in the equipment that follows.

Example No. 1

First appearances

There is a tag attached to the power supply which says ''NO OUTPUT.'' When you are lucky enough to find a complaint tag attached to the defective equipment, pay attention to what it says, because it may give you a valuable hint as to what is wrong. From first appearances, it seems that you will be looking for an open circuit or a short to ground.

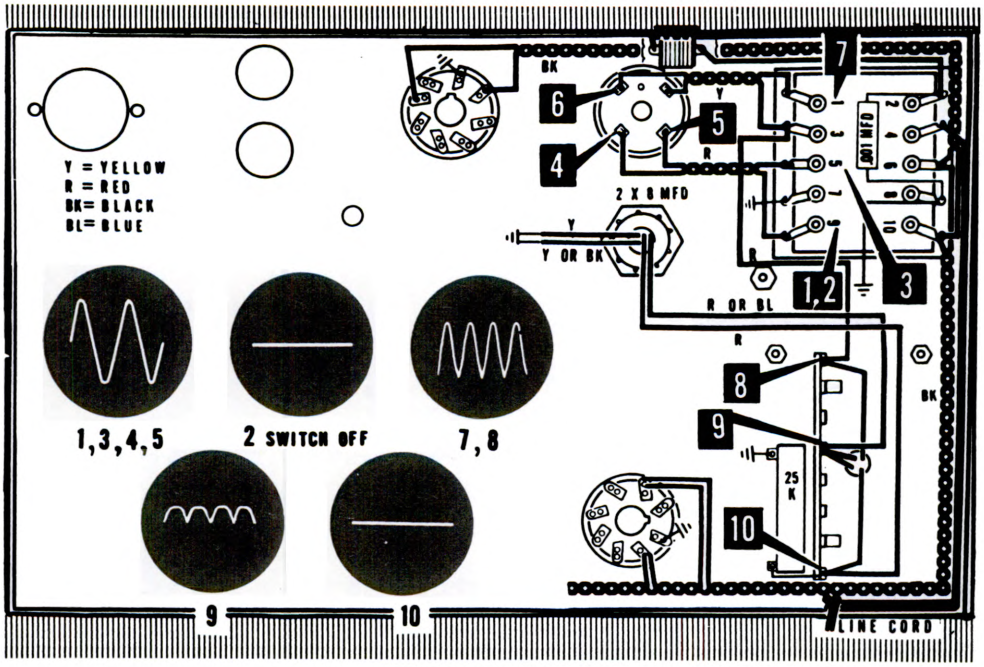
Visual inspection

You notice that Point 9 on the terminal strip has a very loose connection where the lead from the first choke comes to the first filter condenser. You tighten and resolder the connection and make a note of what you did. There is a very fair possibility that you have found the trouble.

Signal tracing

1. You plug in the power supply line cord and connect the d-c voltmeter across the bleeder resistor. There is no output. The loose connection was not the only cause of trouble.

2. Using the oscilloscope, you trace the signal from the transformer secondary, through the rectifier tube, and up to the first choke--the signal is completely normal up to Point 8.



3. When you reach Point 9, which is the output of the first choke, the signal is gone. This could only mean an open between Points 8 and 9. There is little chance of a short to ground, since the transformer is not overheated and there is no loss in signal height as you approach the choke form the preceding test points.

4. An ohmmeter check will show whether you are right or wrong. You pull out the line cord and short Points 9 and 10 to ground with an insulated-handled screw driver to make sure that there is no residual charge on the condensers which might possibly damage the ohmmeter. You connect the ohmmeter across Points 8 and 9 and read infinite ohms. You disconnect the first choke from terminals 8 and 9 and connect the ohmmeter across the ends of the leads--the ohmmeter still reads. The first choke definitely has break in it.

5. You temporarily patch a replacement choke across terminals 8 and 9 and turn on the power supply. The signal now can be traced through the entire circuit without any variation from what it should be, and the d-c voltmeter shows a normal output. The trouble was a damaged choke. It should be replaced, and a final check made both with 'scope and d-c voltmeter.

6. Here is the proof that the choke was the cause of the trouble:

   a. The signal was present at the input to the first choke (Point 8) but there was no signal at the output of the first choke (Point 9).

   b. An ohmmeter check across the suspected choke indicated that it was open.

   c. Replacing the suspected choke with a good one restored normal operation to the power supply.

Example No. 2

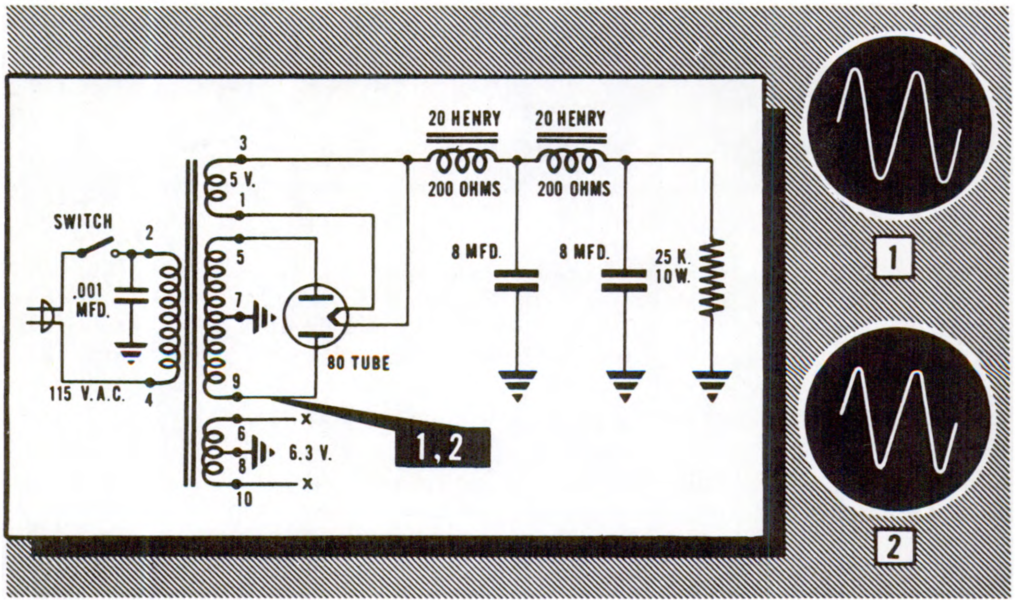
First appearances and visual inspection

There is no complaint tag attached to the power supply. Nothing appears to be wrong.

Signal Tracing

1. A d-c voltmeter connected across the bleeder resistor indicates that the output voltage is correct. Perhaps the defect is excessive hum. You connect the 'scope across the bleeder resistor and you can barely see any ripple, even with the Y GAIN control turned all the way up. The trouble is not excessive hum.

2. Perhaps the defect is an open bleeder resistor. You pull out the power supply line cord and short the high voltage ends of the filter condenser (Points 9 and 10) to ground so as not to damage your ohmmeter. There is barely any spark, showing that the bleeder resistor has drained off most of the charge in a few moments. An ohmmeter check shows that there is nothing wrong with the resistor.



3. There is apparently nothing at all wrong but, before checking the power supply as O.K., you decide to trace the signal through the circuit. Point 1 (the output of one-half the transformer secondary winding) shows a good sine wave. When you shut off the power switch for Point 2, the sine wave does not disappear. Something is wrong with the switch.

4. An ohmmeter check will show whether or not the switch is shorted. You pull out the line cord and short the high voltage ends (Points 9 and 10) of the electrolytic condensers to ground, using an insulated handled screw driver. Connect the ohmmeter across the switch terminals--the scale reads zero ohms. Throw the switch and a short is still there. Since there is nothing visibly wrong with the switch, there is an internal defect and it must be replaced.

5. Replace the switch and recheck the output across the bleeder resistor with the d-c voltmeter. The d-c voltmeter reads zero when the switch is OFF and the proper value when the switch is ON. A check with the 'scope shows good output, with very little hum. The trouble has been repaired.

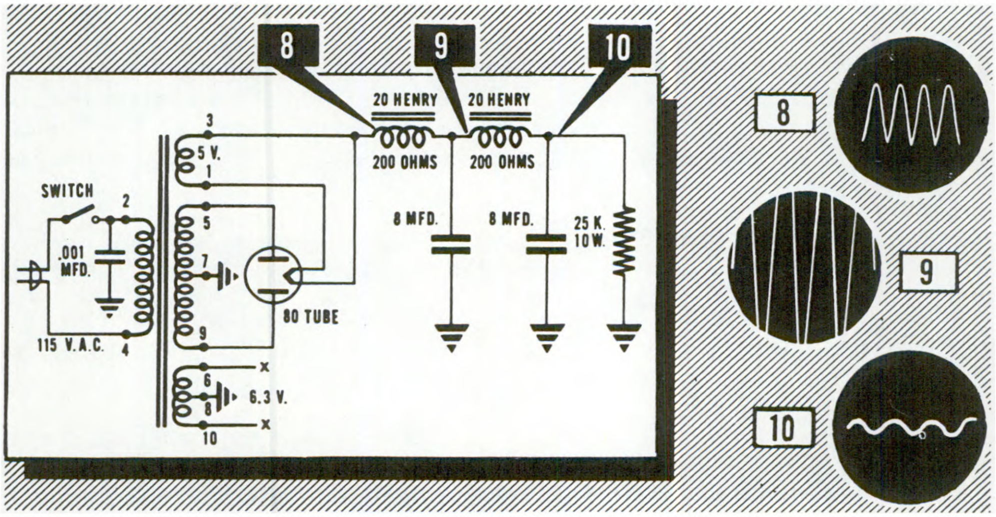
6. It took five steps to find a very simple trouble but, as there was no complaint tag, the procedure you followed was a logical one.

7. Here is the proof that the switch was the cause of the trouble.

    a. Visual checks, output voltage checks, hum checks, and other checks indicate nothing wrong.

    b. A signal tracing check indicated that the signal did not disappear when the line switch was turned OFF.

    c. An ohmmeter check indicated an internal short in the switch.



Example No. 3

First appearances

There is no complaint tag attached to the power supply.

Visual Inspection

There are several slightly corroded connections on the terminal strip to which the chokes and filter condensers are connected. You resolder them and make a note of what you have done.

Signal Tracing

1. You connect a d-c voltmeter across the 25K bleeder resistor, after plugging in the power supply and turning on the switch. The voltage is about 100 volts d-c, which is definitely too low.

2. You connect your 'scope across the bleeder resistor (Point 10) and you notice that there is about 1-1/2 boxes of ripple on the screen with the vertical gain control set maximum. This is excessive hum and it's probably the reason the power supply was sent for repairs.

3. The logical place to look for excessive hum is in the filter section. You connect the 'scope to Point 8, which is the input to the first choke. The signal shows full-wave rectified d-c from the rectifier heater, and there is nothing wrong with it.

4. The next thing to check is Point 9, which is the output of the first choke and the input to the first filter condenser. You observe a great drop in ripple as compared to Point 8, but when you turn up the 'scope Y GAIN control to maximum, the ripple is higher than the full height of the screen. There is something wrong with the first section of the filter and a recheck of Point 10 would not be conclusive until the possible defects in the first choke and filter condenser have been investigated.

5. It is possible that a large number of turns have been shorted out of the choke and an ohmmeter check from Points 8 to 9 would then read less than 200 ohms, but this would not cause a drop in d-c voltage. It is also possible that there is a partial short to ground inside the choke or the electrolytic condenser. You pull out the line cord and discharge the condensers with an insulated handled screw driver. An ohmmeter check from Point 8 to ground reads about 10,000 ohms which bears out the second possibility.

6. You unsolder the condenser lead from Point 8 and the low resistance to ground disappears from Point 8, but is still present when the resistance is measured from the detached end of the condenser. This indicates a leaky condenser. You detach the other condenser lead from Point 10 and patch a good condenser into the circuit for a check.

7. A 'scope check at Point 10 shows hardly any visible ripple, even with the 'scope Y GAIN control turned all the way up. A d-c voltage check from Point 10 to ground shows normal voltage.

8. You have located the trouble, and all that is left to do is to completely remove the old condenser and rewire in the new one.

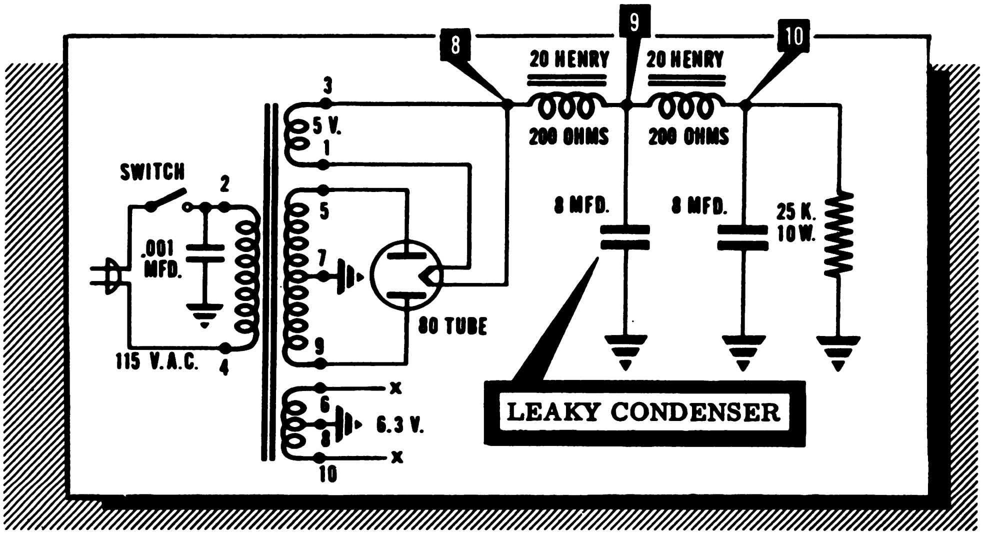
9. Here is the proof that the electrolytic condenser was the cause of the trouble:

   a. There was excessive hum and low d-c voltage at the output.

   b. Signal tracing indicated that the loss in filtering action occurred at the first condenser.

   c. An ohmmeter check indicated that the condenser had an internal low resistance to ground (leaky condenser).

   d. Replacing the condenser restored normal d-c output voltage and very low hum.



JOB SHEET NO. 31

1. With an open filter choke the output is ______________________________.
2. With an open filter choke the voltmeter reads ______________________________ than normal before the choke.
3. With an open filter choke the voltmeter reads ______________________________ after the break.
4. With an open filter condenser the output has greatly increased ____________________ ______________________________.
5. With a leaky filter condenser the voltage output is ______________________________.
6. With a leaky filter condenser the output will show increased ____________________.
7. In a full-wave rectifier if one plate opens, the voltage waveform at the cathode is ______________________________ T__.
8. If the filter condenser shorts, the rectifier tube will ______________________________.

SECTION VII

TOPIC 6

INTRODUCTION TO AMPLIFIERS

A. You have learned: References

1. The uses, types, and component parts of power supplies
2. How the half-wave and full-wave rectifiers work
3. The purpose, types, and advantages of various types of filters
4. The purpose and operation of the bleeder resistor
5. How to troubleshoot power supplies
6. The use and operation of the C.R.O. and tube tester

B. You are learning:

1. What amplifiers do NavPers 10170, pages 19 to 20
2. Uses of amplifiers in Fire Control
3. Types of amplifier tubes
4. Types of amplifiers

WHAT AMPLIFIERS DO

Of the three basic types of electronic circuits--rectifiers, amplifiers, and oscillators--amplifiers are by far the most widely used. The purpose of an amplifier is to take a very small voltage change--one that is so small that it cannot be used--and amplify it many times so that it can run a pair of earphones, drive a loudspeaker, be seen on a 'scope, operate a motor, etc.

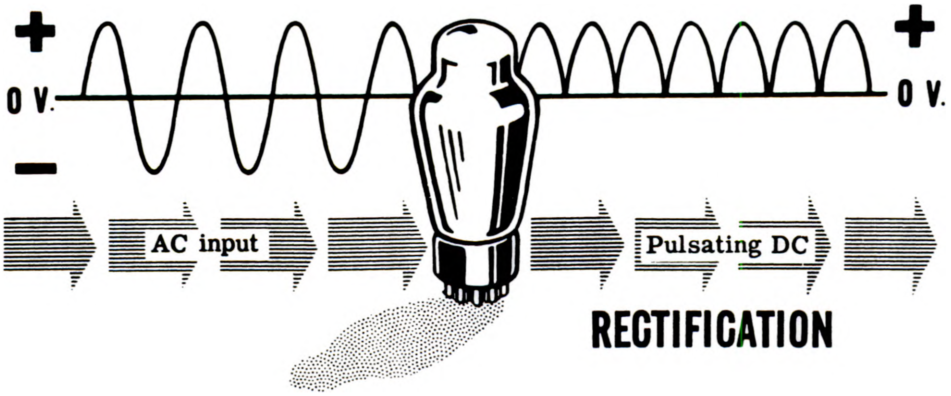
USES OF AMPLIFIERS IN FIRE CONTROL

The purpose of radar and sonar is to pick up "echoes" from distant objects. From the echo that the object returns to the ship, the radar or sonar equipment must be able to show the operator exactly where that object is. The very weak echo must be amplified millions of times before it can drive the various 'scopes, loudspeakers, and other types of indicators which show the location of planes, ships, and submarines to the fire control, radar, and sonar operators.

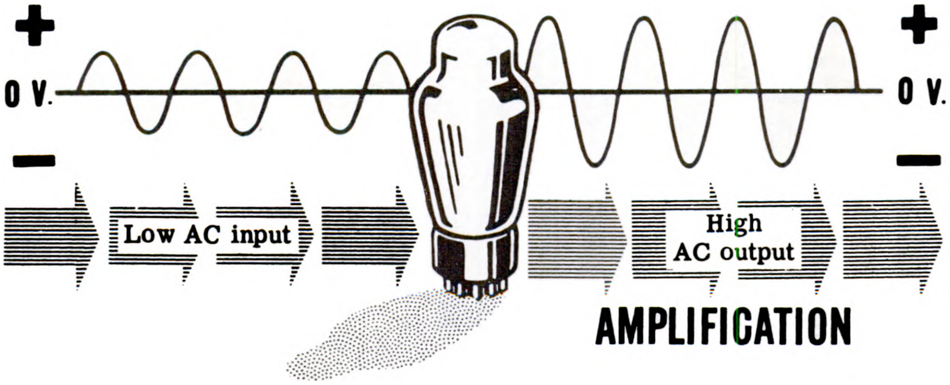
TYPES OF AMPLIFIER TUBES

When you first began your study of vacuum tubes you learned that there are only two main jobs for vacuum tubes to do.

The first job is to change an AC voltage into a pulsating DC voltage. This is called "rectification."

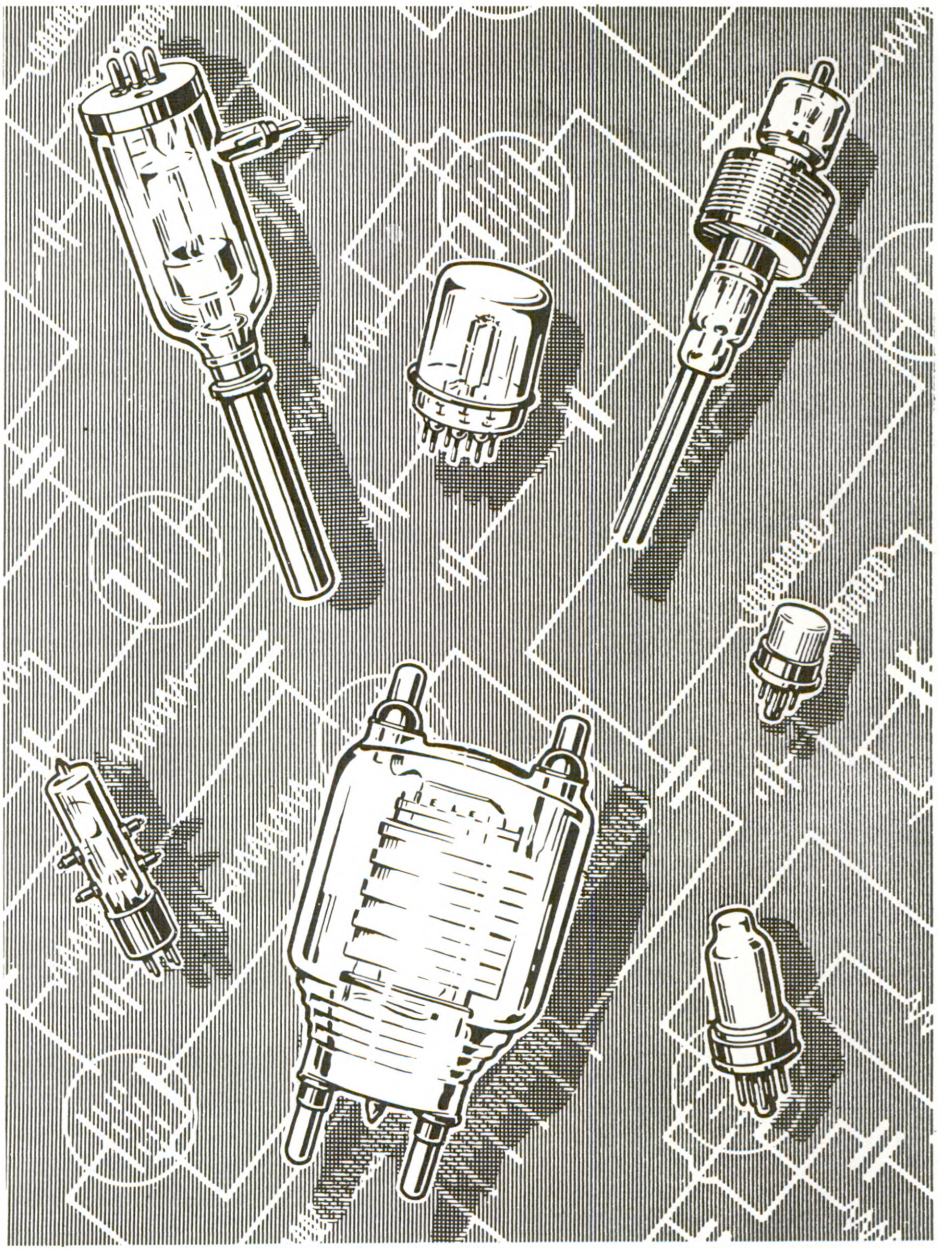


The second job is to change a small AC voltage into a large AC voltage. This is called "amplification."

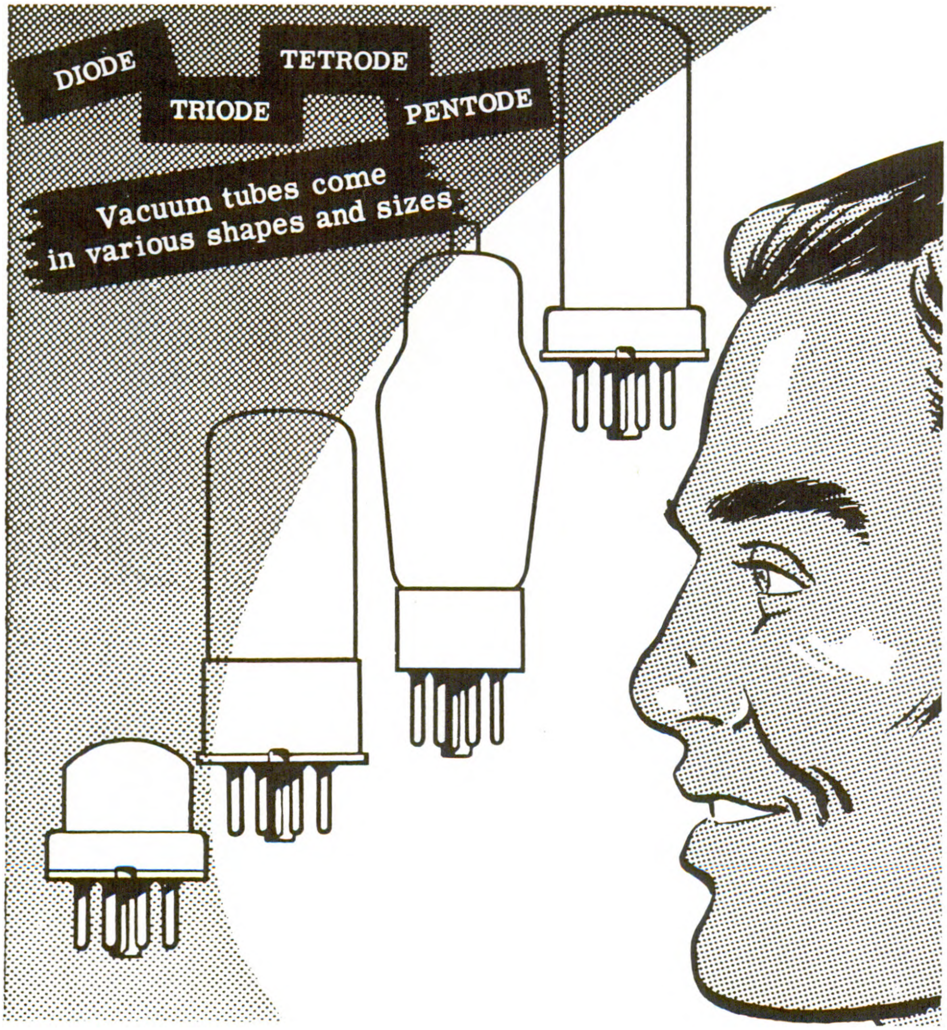


Because of your work with rectifier and power supply circuits, you now know all you need to know about rectification and the diode tubes that are used to do this job. Now you are ready to learn about the second main job a vacuum tube can do--amplification. In this section you will learn about the vacuum tubes that do the job of amplifying small a-c voltages into large a-c voltages.

A recent survey of vacuum tubes manufactured in the United States showed that there are over 1,200 different types of vacuum tubes available! These tubes come in a wide variety of shapes and sizes--enclosed in glass and metal shells.



Most of these 1,200 types can be broken down into four main types. Once you understand these four main types, you will know them all. Whenever you run across a new tube, you will always be able to understand what it does and how it works simply by comparing it to the four main types you know.


DIODE
TETRODE
TRIODE
PENTODE
Vacuum tubes come in various shapes and sizes

Their names describe them by telling how many parts (cathode, grid, plate) there are in the tube. A diode (di = two) has two parts--a cathode and a plate. A triode (tri = three) has three parts--a cathode, a plate, and one grid. A tetrode (tetra = four) has four parts--a cathode, a plate, and two grids. A pentode (penta = five) has five parts--a cathode, a plate, and three grids.

TYPES OF AMPLIFIERS

Amplifiers are designed to amplify only those frequencies which their type of equipment requires, and can be divided into three general groups according to the frequency range of the signals they amplify.

1. Audio amplifiers--These amplify a band of frequencies from 15 cycles per second (cps) to 15,000 cps. This is range of frequencies which the ear can hear--therefore the name "audio." These amplifiers produce a great deal of the amplification in radio receivers, in intercom equipment, in sonar, and in many other types of equipment.

2. Video amplifiers--These are similar to audio amplifiers in that they cover a wide range or band of frequencies and are also similar in design and operation. The frequency band, however, is very much expanded, covering frequencies

from 30 cps to 6,000,000 cps, and higher. Video amplifiers are used primarily to amplify signals for ‘scope presentations in radar and fire control equipment and in television.

3. Radio frequency amplifiers--Unlike the other types, RF amplifiers amplify a narrow band of frequencies, but this narrow band may be anywhere within the wide range of frequencies from 30,000 cps to several billions of cycles per second. They are used in radar, fire control, sonar, radio receivers, and transmitters. When you tune a piece of equipment, such as a home receiver, you are changing the narrow band of frequencies which the set will amplify.

AUDIO AMPLIFIERS IN	VIDEO AMPLIFIERS IN	R.F. AMPLIFIERS IN
● RADIO RECEIVERS ● INTERCOM EQUIPMENT ● SONAR	● TELEVISION ● RADAR ● SONAR ● FIRE CONTROL GEAR	● RADAR ● SONAR ● FIRE CONTROL GEAR ● RADIO RECEIVERS ● TRANSMITTERS

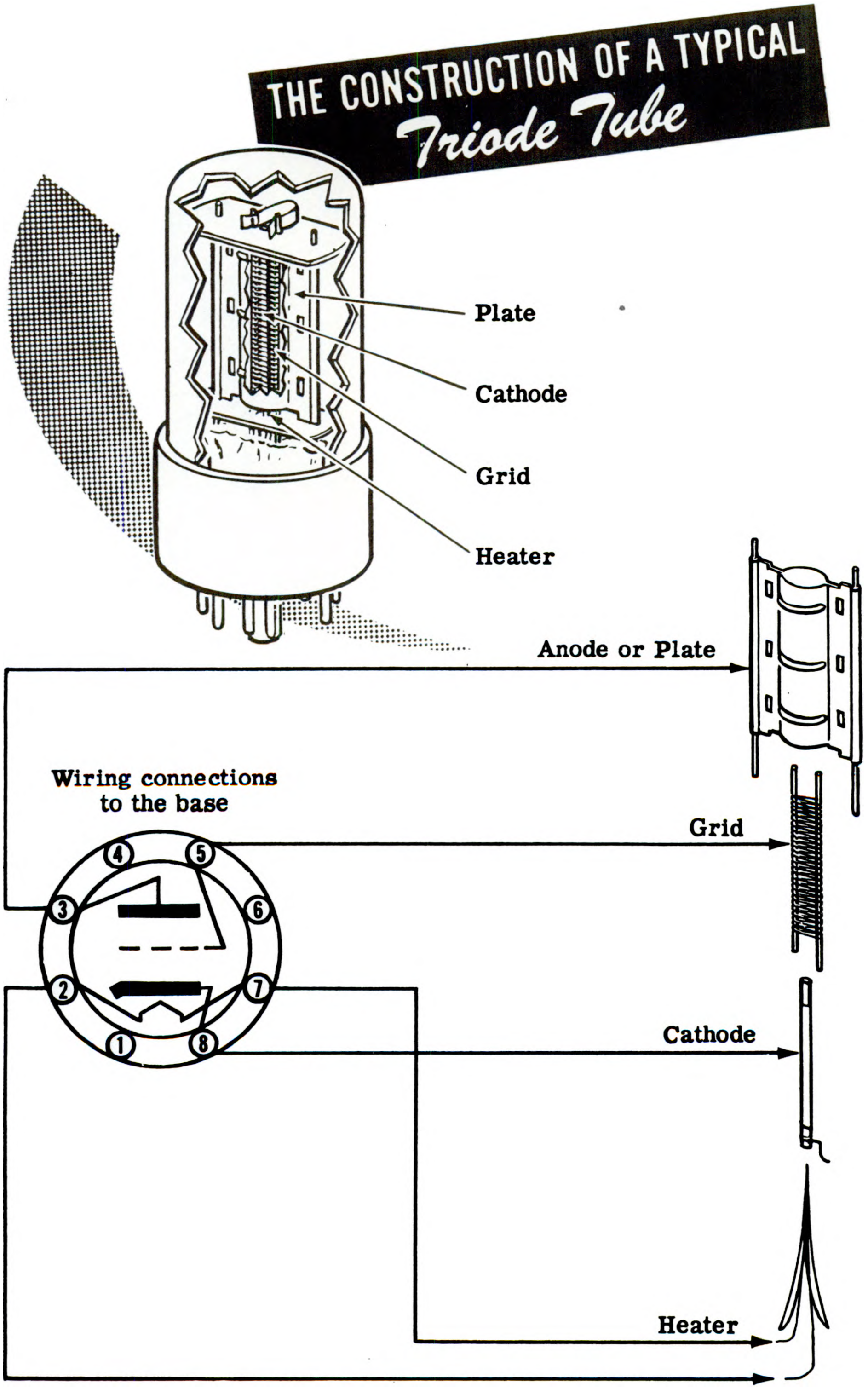
SECTION VII

TOPIC 7

TRIODES

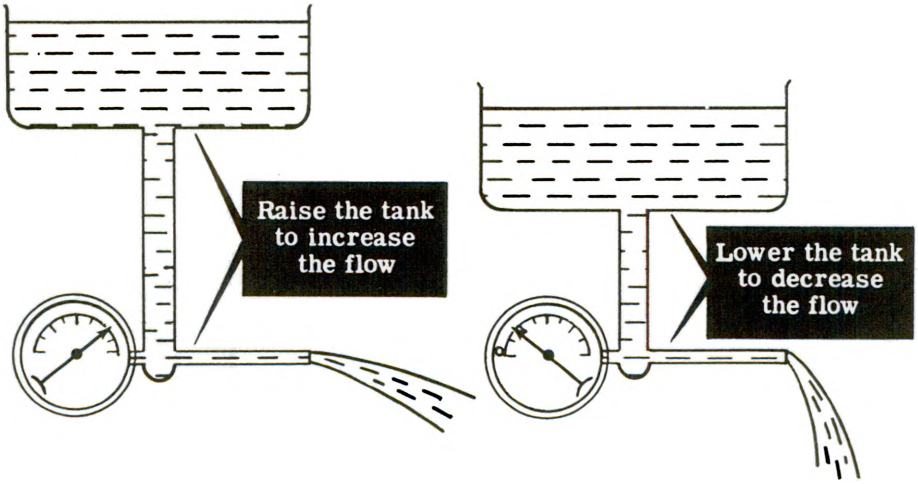
	References
A. You have learned:	
1. The uses, types, compnent parts, and operation of full-wave and half-wave rectifiers	
2. Purposes, types, and advantages of filters	
3. How to troubleshoot power supplies.	
4. The use and operation of the C.R.O. and tube tester	
5. The use and types of amplifiers and amplifier tubes	
B. You are learning:	
1. The construction of the triode vacuum tube	NavPers 10622-B, pages 299 and 300
2. How the triode works	NavPers 10170, pages 344 and 345 NavPers 10622-B, pages 300 and 301
3. Function of the control grid	NavPers 10170, pages 345 to 349
4. The triode as an amplifier	NavPers 10622-B, pages 301 to 306
5. Tube characteristics	NavPers 10170, pages 342 and 350 NavPers 10170, pages 373 to 393 The current tube manual

CONSTRUCTION OF THE TRIODE VACUUM TUBE

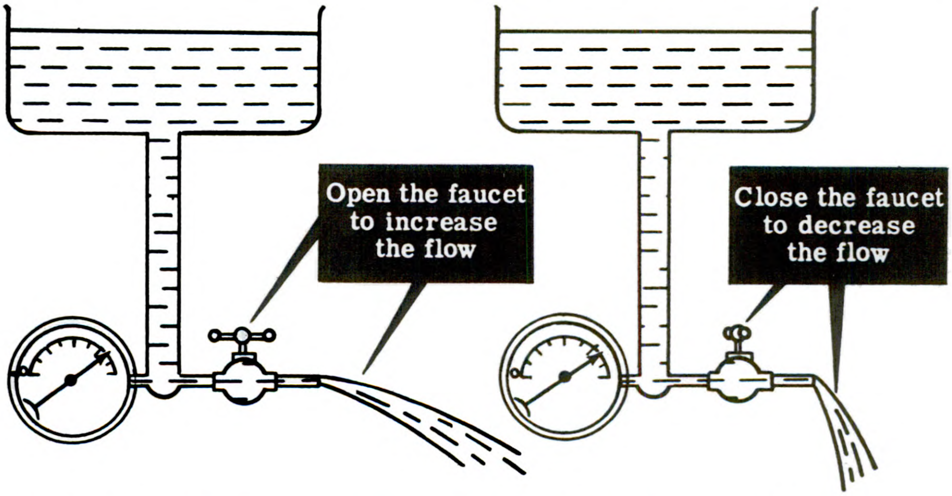


HOW THE TRIODE WORKS

For purposes of explanation, let's compare the triode to the water system shown below. In the water system, you are interested in controlling the flow of water. One way you can do this is by varying the pressure in the system or, in otherwords, changing the height of the water tank.


Raise the tank to increase the flow
Lower the tank to decrease the flow

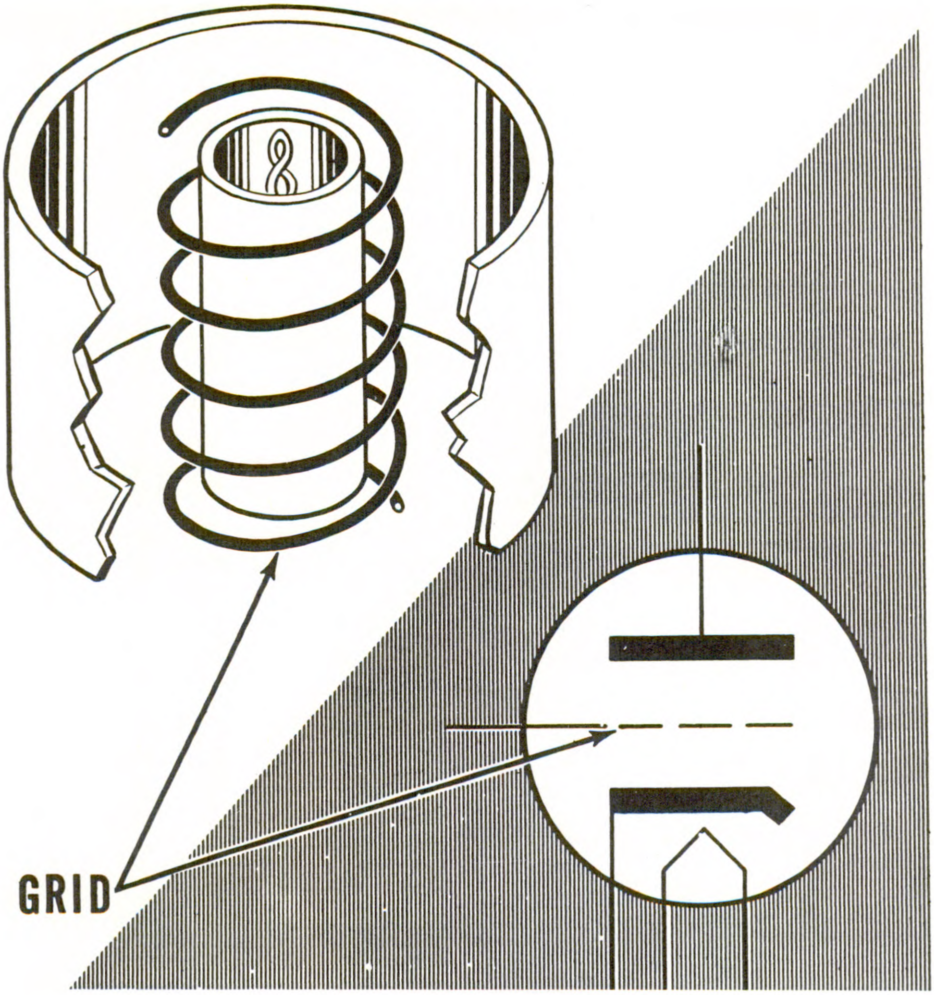
A much more convenient way to vary the flow of water is by using a faucet or valve in the system. Then, by simply turning the faucet, you can control the flow of water. Notice that the water pressure doesn't have to change in order to affect the flow.


Open the faucet to increase the flow
Close the faucet to decrease the flow

This is similar to the way a triode tube amplifies the flow of current. In the triode an additional element, the grid, is placed in the tube, its purpose being to control the flow of current in the tube just as the faucet controls the flow of water. You will see that a small voltage variation on this element produces a comparatively large current variation in the tube.

FUNCTION OF THE CONTROL GRID

This additional structure in the triode is called a "grid" or, more specifically, (to distinguish it from other grids found in tetrodes, pentrodes, etc.) the "control grid." It is a very thin wire wound like a spiral around the cathode so that tube current can pass right through its spacings.

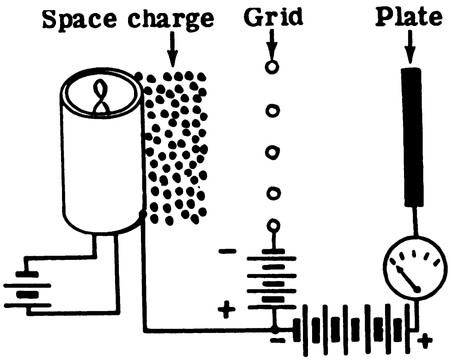


The plate of a triode is normally connected to a high positive voltage, B+. The grid of the triode is usually kept at a negative voltage with respect to the cathode. Because electrons are negatively charged, they tend to be repelled by the negative grid. The grid, being closer to the cathode than is the plate, has a greater effect in controlling the tube current than does the positive plate. If the grid becomes less negative, more electrons will get through to the plate; if the grid becomes more negative, fewer electrons will get through to the plate.

This is what happens when you vary the d-c voltage (called "bias") on the control grid. The plate is very positive and tends to attract electrons. If the grid is negative, it tends to repel electrons.

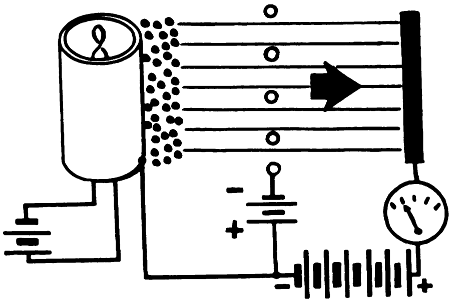
Cut-off

When the grid is made sufficiently negative, its tendency to hold back the electrons will just equal the plate's pull on the electrons and no current will flow. The point at which the two effects are balanced is called "cut-off." When the grid is more negative than this, the tube is operating "beyond cut-off" and no current flows.



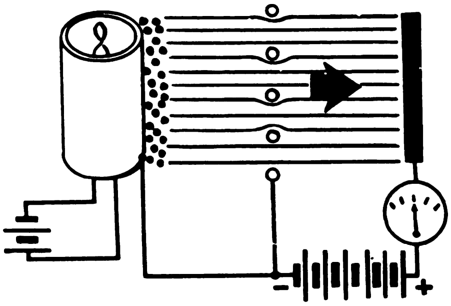
Less than cut-off

When the negative charge on the grid is reduced, a few electrons manage to get from the space charge to the plate.



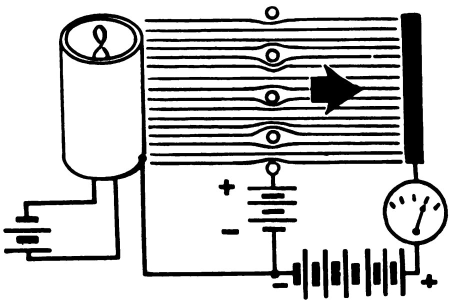
Much less than cut-off

When the grid voltage is reduced further or made equal to zero, more current will flow from the space charge to the plate.



Saturation

If the grid is made positive with respect to the cathode, still more current will flow. A point will be reached when the grid is so positive that the electrons flow from the cathode as fast as the cathode can emit them. This is saturation and a still further increase in grid voltage will not cause an increased current to flow.

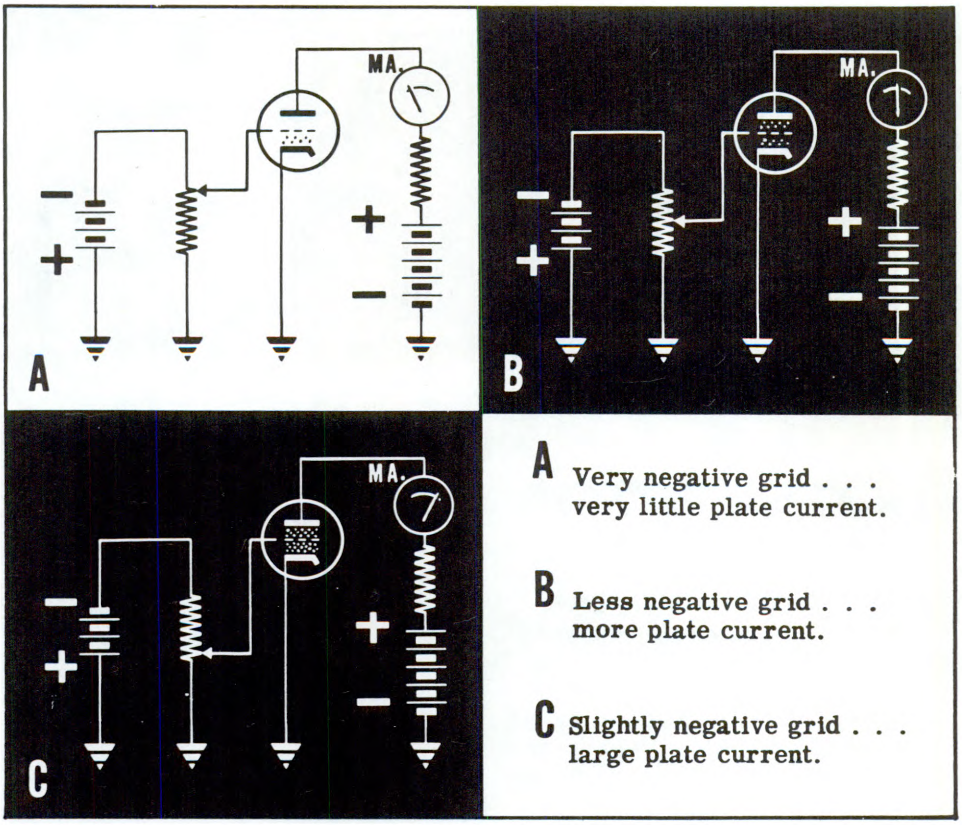


TRIODE AS AN AMPLIFIER

You have found out a little about how important amplifier circuits are in Navy equipment. Now you are ready to find out how they work.

It's all very simple--a vacuum tube does the entire job of amplifying if you provide it with the proper operating voltages and connections. In your experiments with vacuum tubes you will see that if you supply the proper voltages to the various tube elements, a small change in voltage applied to the grid causes a large change in voltage on the plate. The production of a large voltage change from a small change is called "amplification."

You learned that a good way for you to picture the operation of a grid in a vacuum tube was to think of the grid as a valve in a water pipe. The British are so fond of this explanation that, to this day, they call a vacuum tube a "valve." When the grid of the tube is very negative, the "valve" is closed and there is little or no flow of electrons from the cathode to the plate. When the grid voltage is changed so that it becomes only slightly negative, the "valve" is nearly wide open and there is a large flow of electrons from the cathode to the plate.



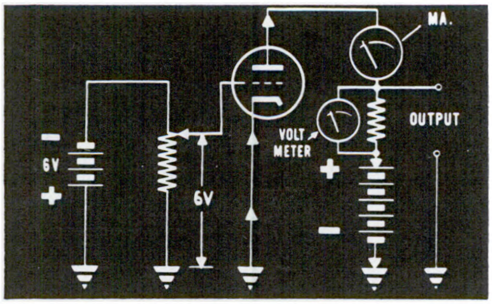
A Very negative grid . . . very little plate current.

B Less negative grid . . . more plate current.

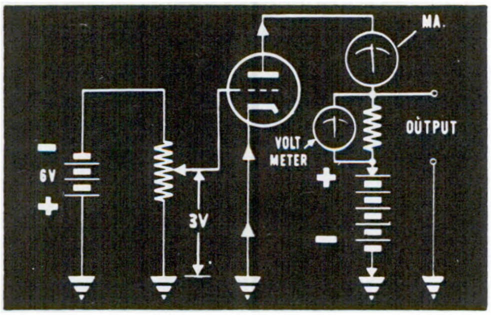
C Slightly negative grid . . . large plate current.

Now a small flow of electrons from the cathode to the plate means that only a small number of electrons flow from the plate to the B+ lead of the power supply and a large flow of electrons from cathode to plate means a large current flow from the plate to the B+ lead of the power supply.

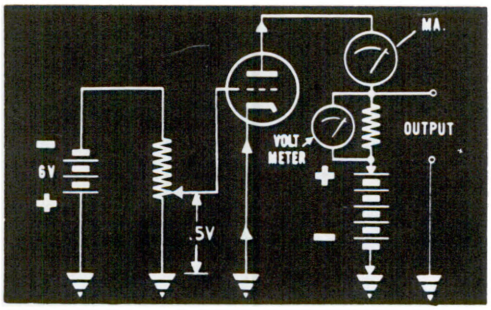
A change in current appearing at the plate of a tube is of no direct use, but, if this plate current change can become a plate voltage change, the original voltage change appearing at the grid will have been amplified. The way to accomplish this is to put a resistor between the plate and B+. You know that whenever the electron flow through a resistance, this voltage change is many times larger than the voltage change on the grid. Since the plate or output voltage changes by the same amount as the voltage across the resistor, the amplified grid voltage change appears at the output.



- **VERY NEGATIVE GRID**
- **VERY LITTLE PLATE CURRENT**
- **VERY LOW VOLTAGE DROP ACROSS PLATE LOAD RESISTOR**



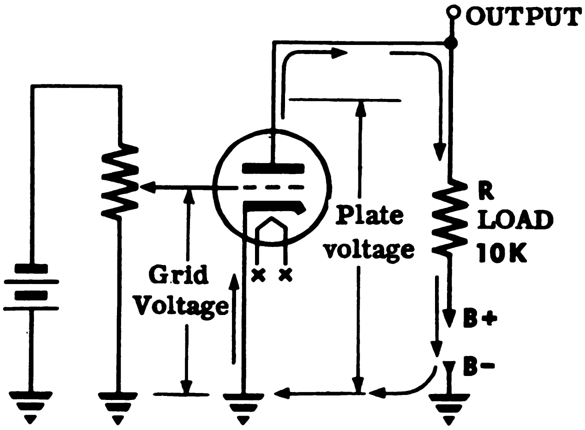
- **LESS NEGATIVE GRID**
- **MORE PLATE CURRENT**
- **LARGER VOLTAGE DROP ACROSS PLATE LOAD RESISTOR**



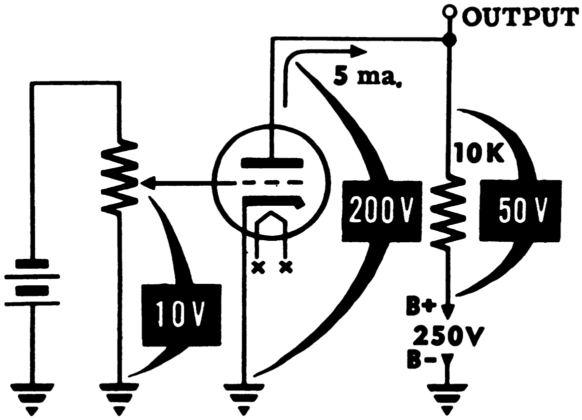
- **SLIGHTLY NEGATIVE GRID**
- **LARGE PLATE CURRENT**
- **VERY LARGE VOLTAGE DROP ACROSS PLATE LOAD RESISTOR**

Using this circuit with certain types of vacuum tubes, the change in plate voltage can be made more than 200 times the change in grid voltage--a voltage gain or amplification of over 200.

Lets take a look at a triode circuit and see how amplification is accomplished. The cathode-to-plate current flows through the load resistor which is in series with the plate and causes a voltage drop across the plate. Therefore, as long as current is flowing, the voltage on the plate is less than B+ by an amount equal to the drop across the load.



Now a slight change in grid voltage causes a large change in plate current and this causes a corresponding change in the voltage drop across the load resistor. If the voltage drop across the load resistor increases, the plate voltage will decrease by the same amount. This change in plate voltage is called the "output voltage." Because a change in grid voltage produces a much larger change in plate voltage, the triode amplifies.



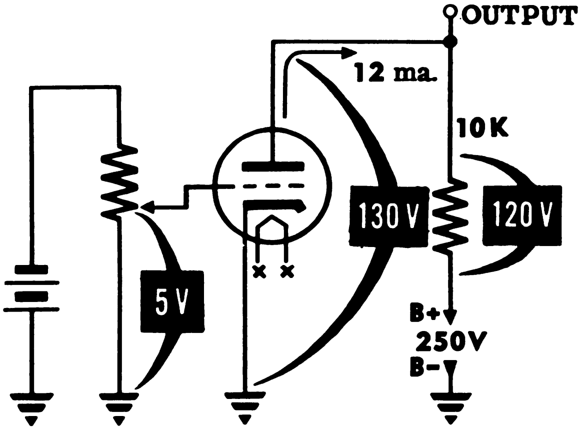
Here is an example of what happens in an actual tube: With the grid voltage = -10 volts, load resistor = 10K ohms, B + = 250V, the plate current that flows is 5 ma. This current causes a voltage drop across the load of E = IR = .05 x 10,000 = 50 volts. Therefore, the plate voltage is 200 volts (250 - 50).

Now let's change the grid voltage from -10 volts to -5 volts (less negative). The current increases to about 12 ma., the drop across the load is 120 volts--an increase of 70V, and the voltage on the plate is now only 130 volts--a decrease of 70V. Note that the sum of these two voltages still adds up to the B + voltage of 250V. Thus, a change of only 5 volts on the grid has changed the plate voltage 70 volts--an amplification of 14 times.

TUBE CHARACTERISTICS

Amplification Factor

Since the grid voltage and plate voltage can be used to control the flow of current to the plate, it is important to see which does the better job. If you look at the results of the tests, you will see that a small change in grid voltage can produce a large change in plate current while a much larger change in plate voltage is necessary to produce the same plate current change.

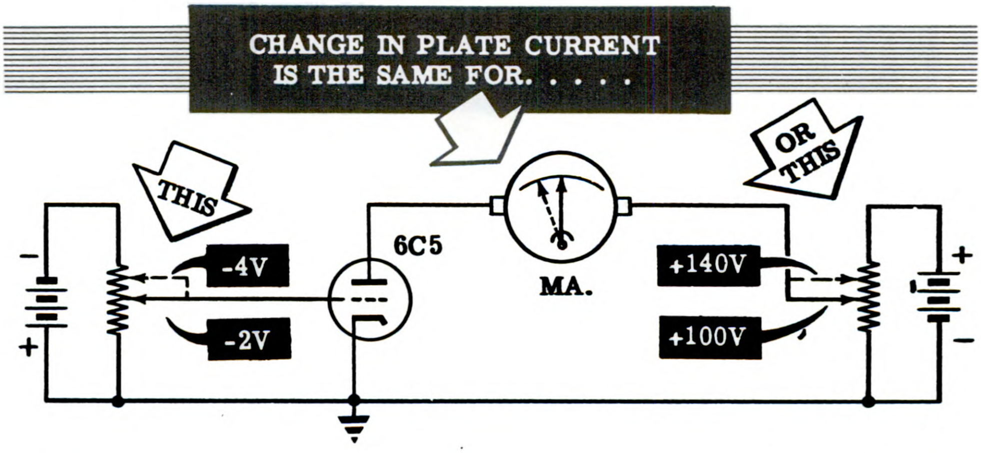


From these results we can say that the grid of the tube is much more effective than the plate in controlling plate current.

The ratio of the effectiveness of the grid and plate in controlling plate current is called Mu, and the Greek letter μ is used to represent it.

$$\mu = \frac{\text{Change in plate voltage}}{\text{Change in grid voltage}} \text{ to produce the same change in plate current}$$

Actually the Mu of tube is much more than a ratio. It tells you how much a vacuum tube is able to amplify a signal that is applied to its grid. For example, suppose you find that when the grid voltage is changed from -2 to -4 (a change of 2V) the plate current changed the same amount as it did when the plate voltage was changed from 140V to 100V (a change of 40V). The ratio of these two voltage changes is 20 to 1, which means, that if one volt of a-c is applied to the grid of the tube, 20 volts of a-c will appear in the plate circuit. The tube, therefore, has amplified an a-c signal 20 times. For this reason the Mu of a tube is also known as the amplification factor.



$$\mu = \frac{40}{2} = 20$$

Plate Resistance

The plate resistance of a tube is internal opposition offered, between the cathode and plate, to the flow of the alternating component of plate current. When the tube is operating with a-c voltage on the grid, the number of electrons flowing to the plate changes, and this affects the internal or plate resistance of the tube.

This plate resistance is the ration of a change in plate voltage to a change in plate current with the grid voltage constant. Suppose the test curve indicates that a change in plate voltage from 100V to 150V produced a change in plate current of 5 ma. Since the plate resistance is

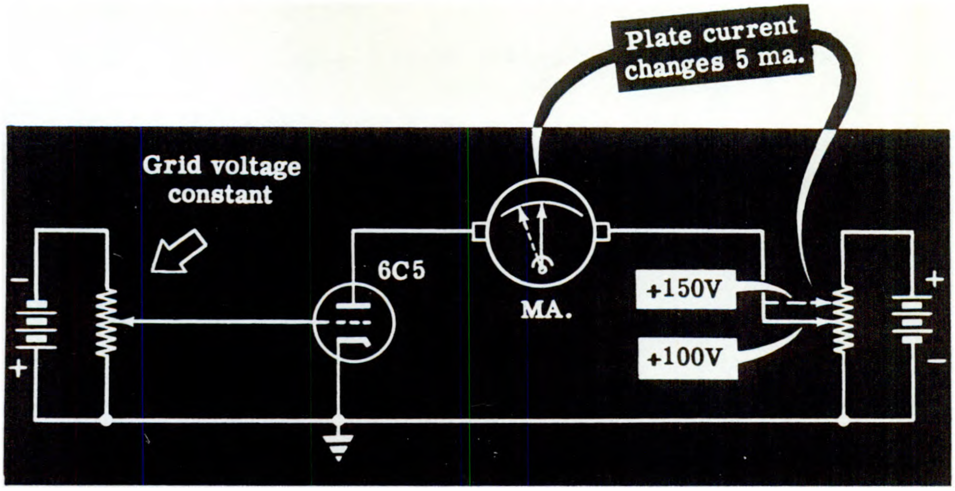
$$r_p = \frac{\text{Change in plate voltage}}{\text{Change in plate current}} \text{--for a constant grid voltage}$$

then

$$r_p = \frac{50}{.005} = 10{,}000 \text{ ohms.}$$

The plate resistance is not the same for all vacuum tubes. For triodes it will range from 2,000 to 100,000 ohms and for pentodes it may be as high as 1 megohm.

DETERMINING THE PLATE RESISTANCE OF A TRIODE



Transconductance

So far you have learned about two characteristics of vacuum tubes--the μ or amplification factor and the internal plate resistance, r_p. Another characteristic--transconductance--is obtained from the relationship of μ and r_p. Transconductance is a measure of how effective the grid is in controlling plate current and it is expressed as the ratio of μ to r_p.

$$\text{Transconductance } (g_m) = \frac{\mu}{r_p} \text{ in mhos}$$

In simplified form, g_m represents the effect of a changing grid voltage or plate current with the plate voltage held constant.

The g_m of a tube is expressed in micromhos which is one millionth of a mho, pronounced "mo"--ohm spelled backwards. It is used as the unit of transconductance since conductance is the opposite of resistance.

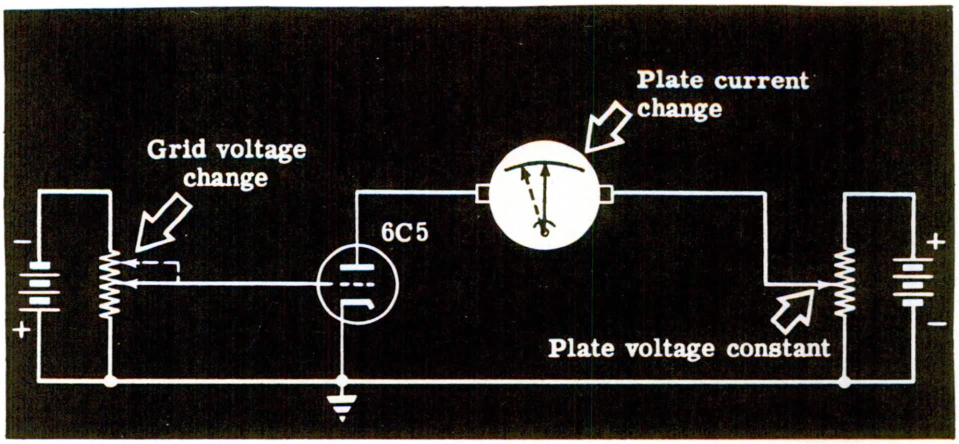
Using the μ and r_p from the previous sheets, the g_m of the tube can be determined.

$$g_m = \frac{\mu}{r_p} = \frac{20}{10,000} = .002 \text{ mhos}$$

$$g_m = 2000 \text{ micromhos}$$

For most vacuum tubes, the transconductance is usually several thousand micromhos. Tubes with a high μ and low r_p will have a high g_m.

DETERMINING THE TRANSCONDUCTANCE OF A TRIODE



JOB SHEET NO 32

1. The control grid is a spiral of fine conducting wire surrounding the

____

2. The control grid controls the ______________________________.

3. The control grid ________________________ from all other electrodes within the tube.

4. The control grid contact terminal is at ______________________ or ____________________.

5. The amount of change in lp produced by a one-volt change in Eq with Ep held constant is __________________________________.

6. The _________________________ is an index of how many times more effective Eq is than Ep in controlling lp.

7. The opposition to alternating current flow between the cathode and plate is the

____________________________.

8. The grid voltage has a greater effect on lp than on Ep because ______________________

_________________________________.

9. If the a-c signal exceeds the bias level, the grid will __________________________.

10. Negative grid bias is used so that ____.

SECTION VII

TOPIC 8

TRIODE AMPLIFIER

A. You have learned:	References
1. Uses, types, component parts, and operation of rectifiers, filters, and amplifiers	
2. How to troubleshoot power supplies	
3. Use of the C.R.O. and tube tester	
4. Construction and function of the triode	
5. Tube characteristics	
B. You are learning:	
1. Grid bias voltage	NavPers 10170, pages 350 to 353
2. Classes of amplifiers	
3. Sources of bias	NavPers 10170, pages 384 to 386

GRID BIAS VOLTAGE

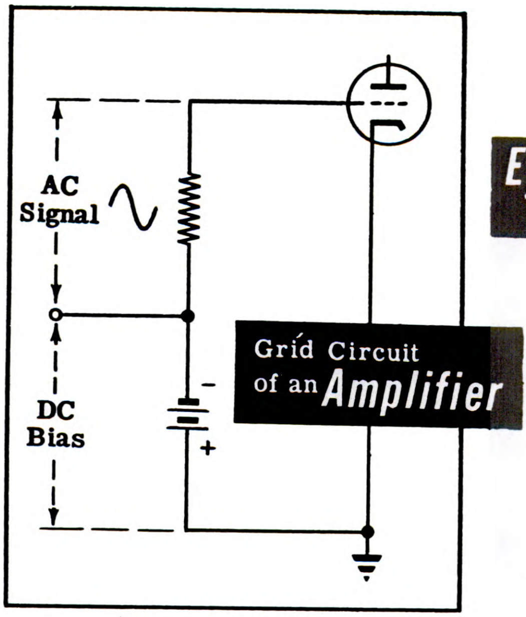
We are concerned with triodes used as amplifiers, and for this purpose they are normally operated with the grid negative to prevent distortion of the signal. This confines the operation to the left portion of the Eg-Ip curve (Test 1). The voltage which keeps the grid negative is called the "grid bias voltage." Grid biasing is simply the process of making the grid negative with respect to the cathode.

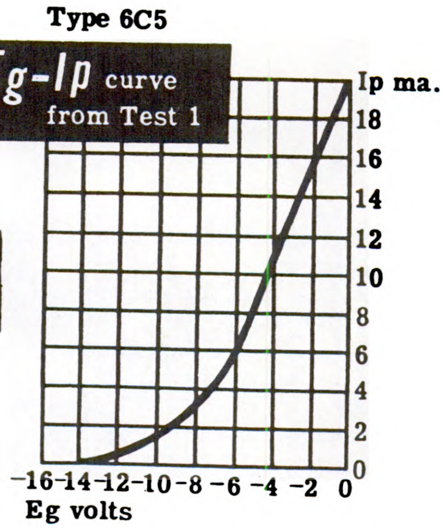
When a tube is used as an amplifier, two voltages in series are applied between grid and cathode.

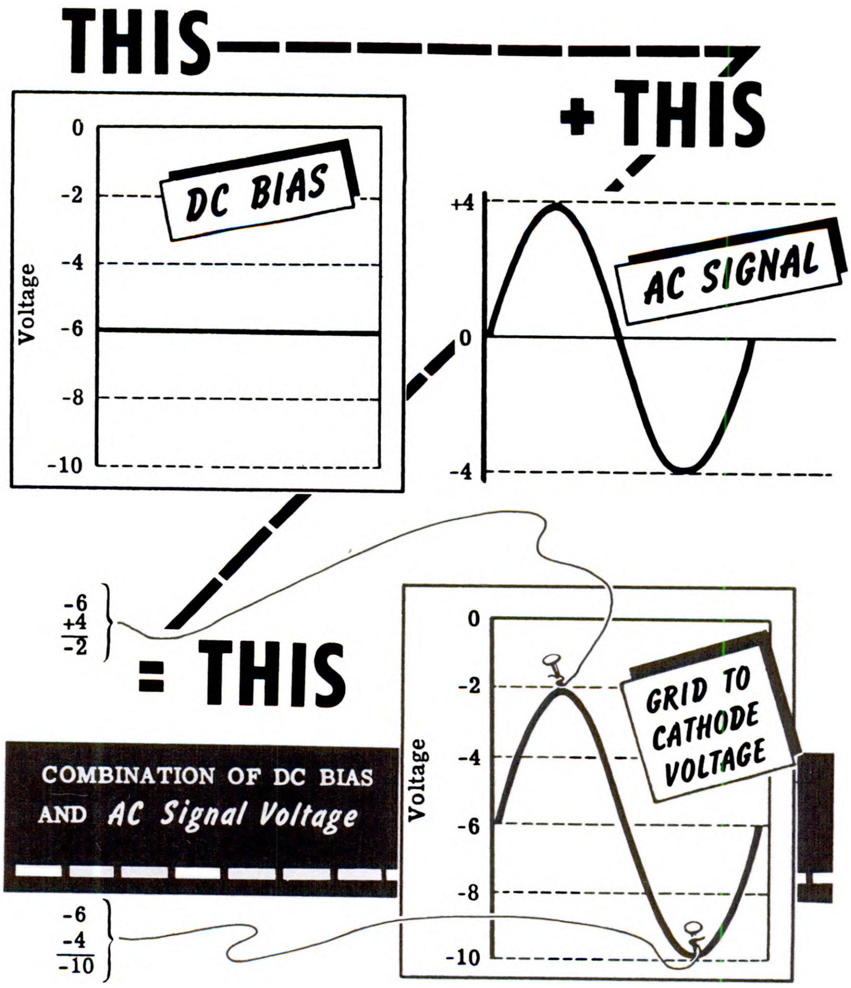
1. The negative d-c grid bias voltage which fixes the point of operation on the Eg-Ip curve. This bias voltage may be obtained from a battery or any other source of d-c voltage. Various types of bias supplies will be discussed later.

2. The a-c signal voltage, which for the present will be in the audio frequency range.

In the sheets which follow, you will see how the a-c signal adds to and subtracts from the bias voltage to produce corresponding changes in plate current.


AC Signal
DC Bias
-
+
Grid Circuit of an Amplifier


Type 6C5
Eg-Ip curve from Test 1
Ip ma.
18
16
14
12
10
8
6
4
2
0
-16 -14 -12 -10 -8 -6 -4 -2 0
Eg volts


THIS
DC BIAS
0
-2
-4
-6
-8
-10
Voltage
+ THIS
AC SIGNAL
+4
0
-4
-6
+4
-2
= THIS
COMBINATION OF DC BIAS AND AC Signal Voltage
GRID TO CATHODE VOLTAGE
0
-2
-4
-6
-8
-10
Voltage
-6
-4
-10

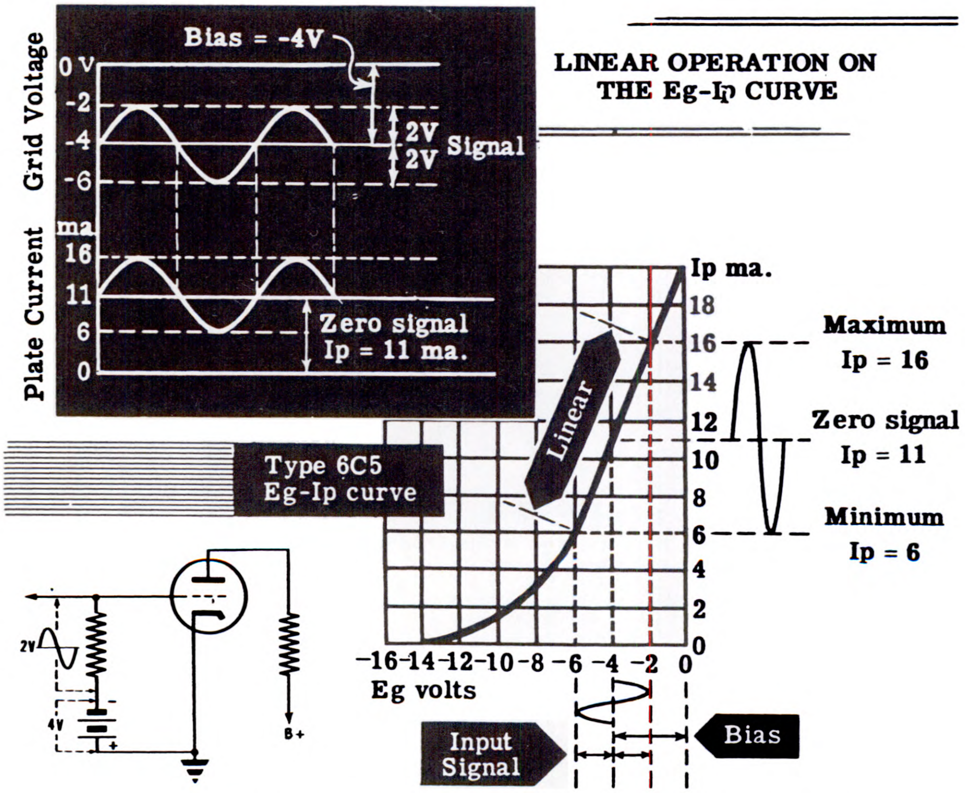
If an a-c signal is applied to the grid, the current flowing in the plate circuit will vary in the same manner as the signal voltage. The positive half-cycle of the applied signal voltage is in series opposing with the bias voltage and, therefore, subtracts from it. The negative half-cycle of the signal voltage is in series aiding with the bias voltage so that addition of the two voltages takes place. As a result, the a-c signal voltage causes the grid to cathode voltage to be alternately less negative and more negative. This varying negative voltage between grid and cathode allows more and less current to flow so that the plate current variations will be a duplicate of the applied signal voltage.

Let us consider the following example which will illustrate the points just made. Suppose a 6C5 triode is connected in a circuit with -4V bias voltage applied, the plate current will be a steady 11 ma. This can be seen by referring to the Eg-Ip curve.

When an a-c signal of 2V is applied to the grid, the positive half-cycle will subtract 2V from the bias, causing the grid to cathode voltage to change from -4V to -2V. The negative half-cycle will add to the bias and cause the grid to cathode voltage to change from -4V to -6V. You can see that the grid to cathode voltage is varying from -2V to -6V around the -4V bias.

The plate current depends on the amount of negative voltage between grid and cathode. This negative voltage is now varying in the same manner as the applied signal. Therefore, the plate current will vary in accordance with the applied signal.

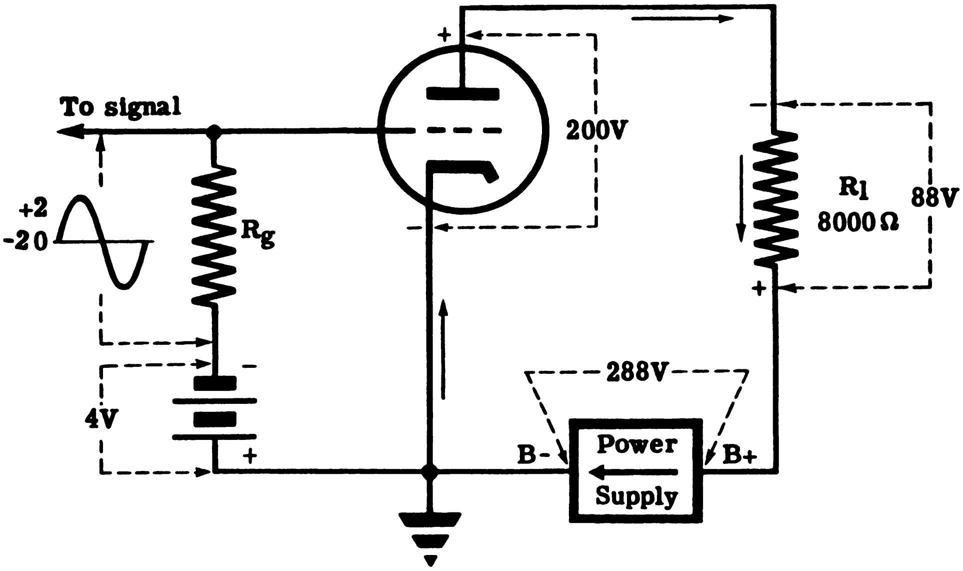
When the grid voltage varies so that the plate current varies in accordance with the applied a-c signal, the amplifier is called "Class A," and is operating on the linear portion of the Eg-Ip curve. You will learn more about classes of operation a little later.



LINEAR OPERATION ON THE Eg-Ip CURVE

To obtain an amplified output voltage at the plate we must use the plate current variation. In the example on the previous sheet, a 5-ma. a-c component was produced in the plate circuit by applying a 2V a-c signal to the grid.

Suppose we look at the plate circuit of the triode. If an 8,000 ohm plate load resistor (RL) is used, the steady or zero-signal plate current of 11 ma. will produce a d-c voltage drop across the load of E I x R .011 x 8000 88V. The d-c plate voltage is 200V and the total d-c voltage (B+) is the sum of the load voltage and plate voltage, or 288V.



D-C VOLTAGE DISTRIBUTION ... IN A TRIODE AMPLIFIER

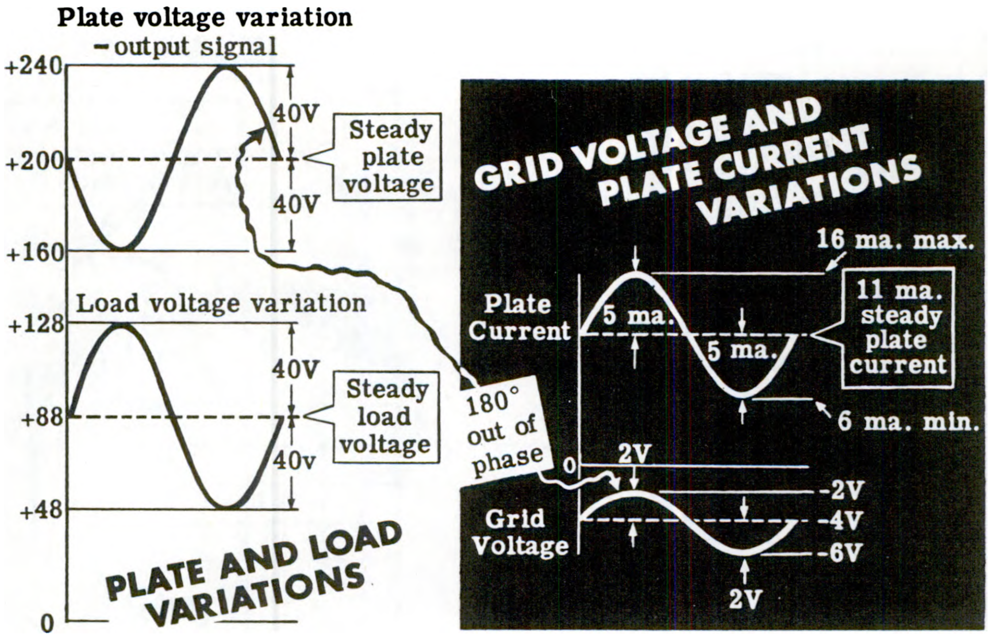
On the next sheet you will see how the load voltage and the plate voltage change when the signal is applied to the grid.

When the signal is applied to the grid, the plate current increases to 16 ma. (5 ma. increase) and decreases to 6 ma. (5 ma. decrease). When 16 ma. flows through the load, will be E=I x R=.016 x 8000 = 128V, and increase of 40V (128 - 88 = 40V). This will make the plate voltage decrease 40V since the total voltage must always add up to the B+ voltage of 288V. Therefore, the plate voltage will decrease from 200V to 160V. (Note: 160V + 128V = 288V.)

When the plate current decreases to 6 ma., the voltage drop across the load will be E = I x R = .06 x 8000 = 48V, a 40V decrease from its steady value of 88V. Since the total voltage must still be up to 288V, the plate voltage will increase from its steady 200V to 240V. (Note: 240V + 48V = 288V).

You can see from the illustration below that the 5 ma. a-c component of plate current produces a 40-volt variation across the plate load resistor and an equal and opposite variation in plate voltage. Since a 2V a-c signal on the grid initially produced the plate current variation, the 40V signal at the plate is an amplified version of the grid signal.

A 2V signal on the grid has produced a 40V signal at the plate, which means that we have amplified the signal 20 times. Note that this amplified signal at the plate is 180 degrees out-of-phase with the signal on the grid.

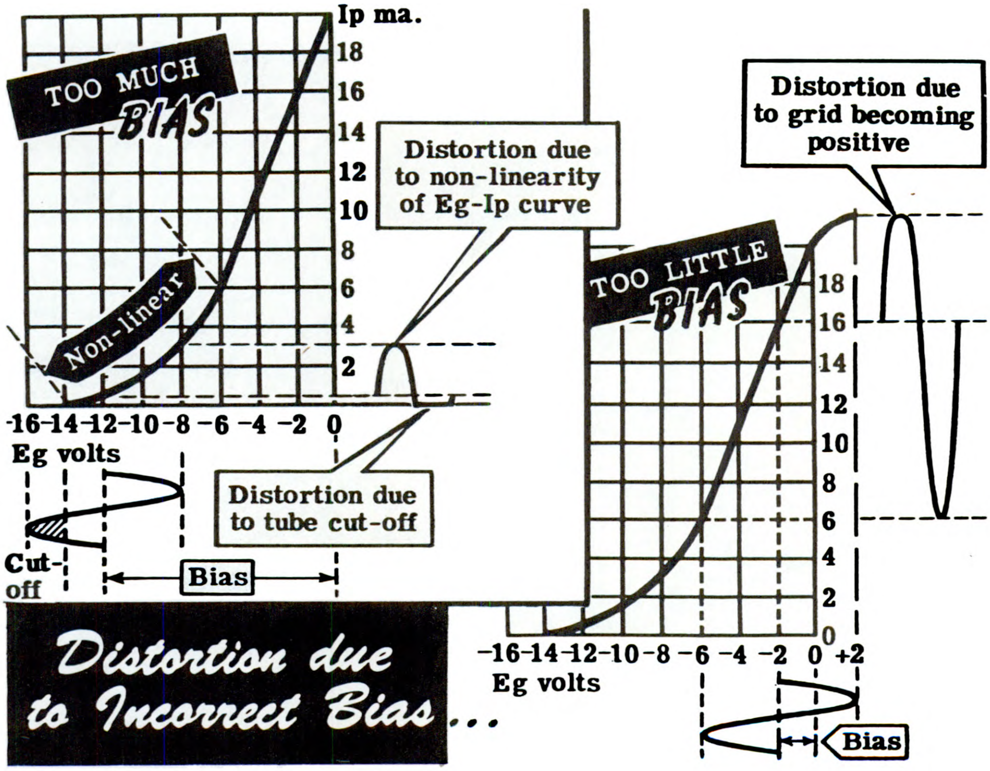


You will see on the next sheet that the correct bias is necessary if the plate current variation, and likewise the plate voltage variation, is to be an exact duplicate of the grid signal.

Notice that although the signal itself was positive during one-half cycle, the grid to cathode voltage was never positive--it just became more negative or less negative. The bias point for this amplifier was selected so that it fell in the center of the straight-line or linear portion of the Eg-Ip curve. Operation on the linear portion is essential if the output waveform is to have the same shape as the input waveform. Operating at incorrect bias voltage will produce distortion of one form or another. If too much bias is used (making the grid voltage more negative), the signal will drive the tube into cut-off during the negative half-cycle and produce a distorted plate current variation. If too little bias is used, the signal will drive the grid to take some electrons from the cathode that would normally have gone to the plate. Again the result is a distorted plate current variation. These conditions are illustrated below.

Distortion will result with the correct bias voltage if the input signal is too large. The large signal will drive the grid into both the positive and the cut-off regions--producing distrotion.

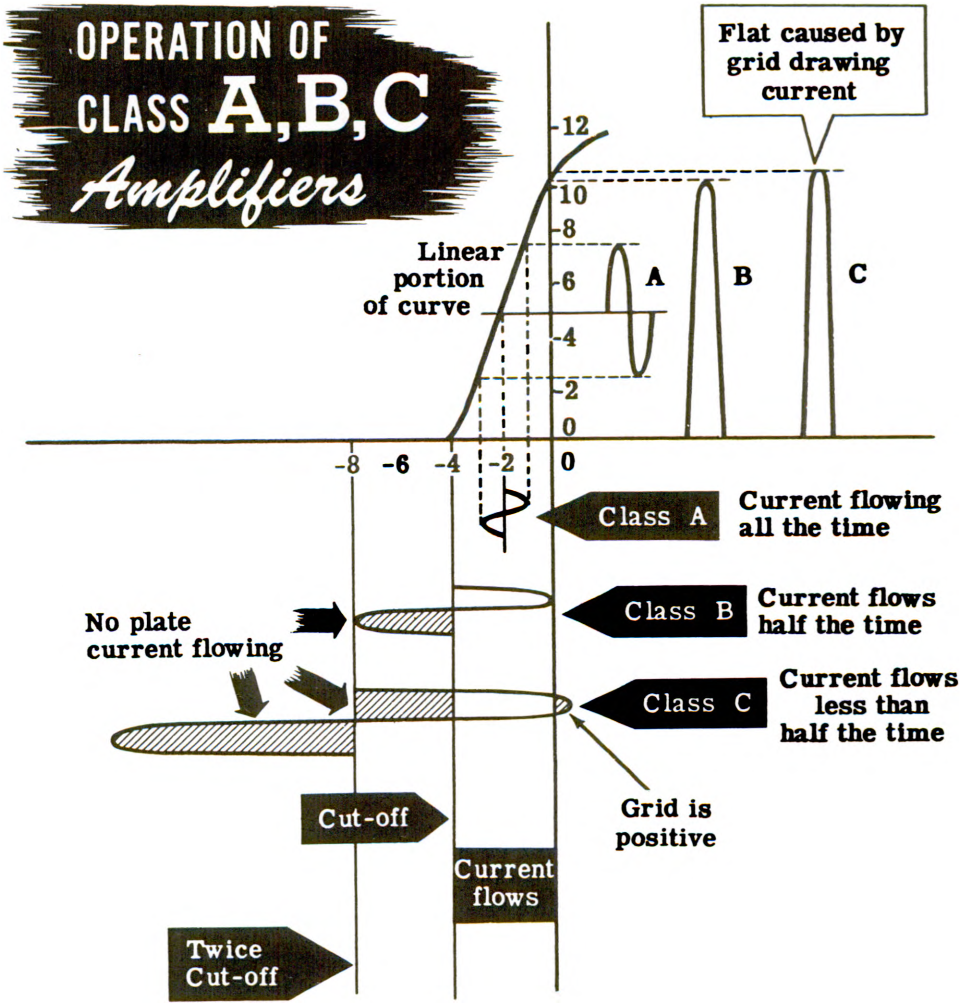
You can now see that proper bias is necessary if the plate current variation is to look exactly like the grid signal variation. If the amplifier tube is biased in the center of the linear portion of Eg-Ip curve and the tube is not overdriven (excessive signal), very little distortion will result. Incorrect bias will result in a distorted output signal.



THE CLASSES OF AMPLIFIERS

The class of an amplifier is determined by its point of operation on the Eg-Ip curve. There are three major classes of amplifiers: Class A, B, and C. Class A amplifiers are biased to operate in the center of the linear portion of the Eg-Ip curve. The amplifier described in the previous sheets is a Class A amplifier. Class B amplifiers are biased to operate near cut-off, and Class C amplifiers operate at a point where the bias voltage is equal to twice the cut-off voltage of the tube.

The following figure shows the bias voltages for the three different classes of amplifiers. For this particular tube, the bias would be -2V for Class A operation. Since Class B operates at cut-off, its bias voltage must be -4V. For Class C operation, the bias must be -8V because a Class C amplifier operates at a bias equal to twice the cut-off value.



The figure shown on the previous sheet is a comparison of the operating characteristics of Class A, B, and C amplifiers. This is what you should see from the illustration.

Class A

The signal is small. It is never large enough to drive the grid either positive or beyond cut-off. Plate current flows during the complete cycle of signal input. The plate current variation is an exact duplicate of the grid signal.

Class B

The signal is larger than for Class A. The grid may be driven positive. The signal drives the grid beyond cut-off for approximately half the input cycle. Only the positive half-cycle of input appears in the plate circuit. The total plate current change is much greater than the change produced by Class A operation. Plate current flows for approximately half the complete cycle. Plate current is zero when no signal is put into the grid.

Class C

The applied signal is the largest of the three classes. The grid is driven beyond cut-off and into the positive grid region. The plate current variation is the largest of the three classes. The peak of the current wave has a dip because the contol grid is drawing current, thereby reducing the amount of current available to the plate. Plate current flows for less than half a cycle on input voltage. Without a signal on the grid, no plate current flows. A large signal voltage is necessary to drive the grid positive during each cycle. This class is used only in RF (radio frequency) power amplifiers.

The Class A amplifier is used primarily as a voltage amplifier. Class B and Class C amplifiers are used as power amplifiers and are designed to deliver high currents.

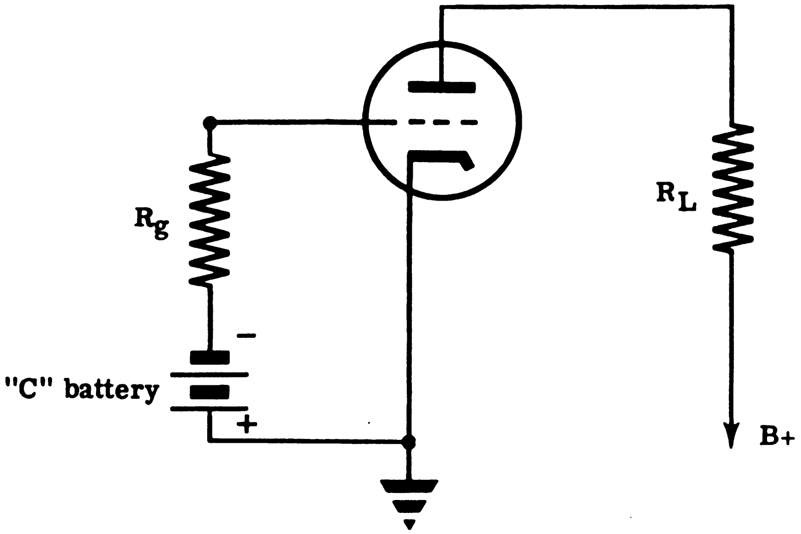
There are combinations of Class A and Class B amplifiers and these are called Class AB1 and AB2. Class AB1 amplifiers are biased to a point slightly more negative than Class A amplifiers. Class AB2 amplifiers are biased to a point slightly less negative than that of Class B. These classes of opperation are actually compromises between Class A and Class B.

SOURCES OF BIAS

Battery Bias

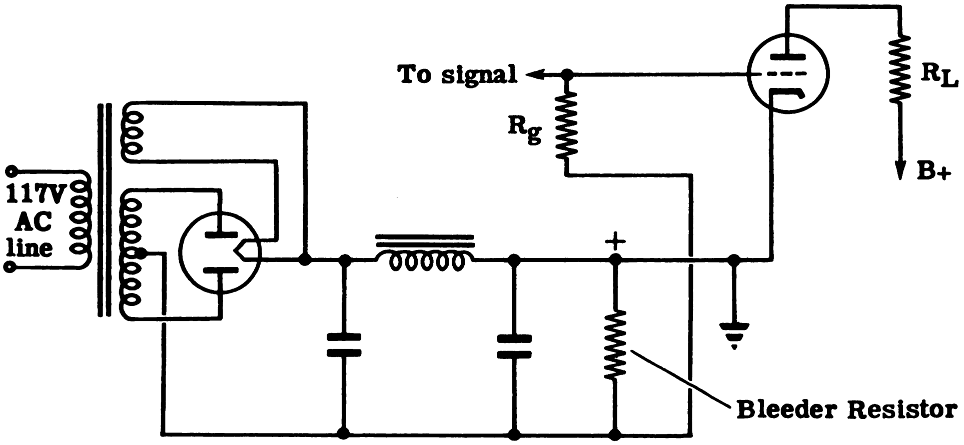
Battery bias was chosen for the first illustration of bias because it is the easiest to understand. In actual practice, you will find it used only in the laboratory or for experiment work. The battery type is reliable and efficient, but the size and weight of batteries make it difficult to use in most equipment.

Whenever batteries are used as a source of bias voltage, it is desirable to use a combination of cells in series that add up to the required voltage. With this arrangement, it is not necessary to use regulating devices, such as potentiometers, which draw current from the battery and gradually consume its power. Most bias or ''C'' batteries are made in multiples of of 4-1/2 volts 4-1/2, 9, 18 volts and higher. These batteries are tapped for intermediate voltages. The negative terminal of the battery is connected to the grid through the resistor Rg, the positive terminal is connected to the cathode. This makes the grid negative with respect to the cathode.

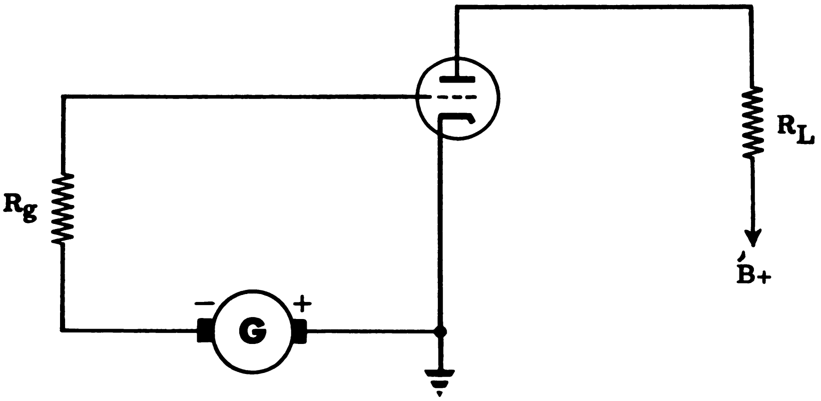


Power Supply Bias

Rectifier power supplies replace "B" batteries in the plate circuit and also are used to replace the "C" batteries. In large equipment, such as some Navy transmitters, a separate bias power supply is used. It may be a generator, a half-wave rectifier, or a full-wave rectifier. The positive side of the power supply is connected to the cathode and the negative side is connected to the grid, just as is done with a "C" battery. In the illustration below, the positive terminal of the bleeder resistor is connected to ground and the negative terminal is connected to the grid through Rg. Since the cathode is grounded, the grid is negative with respect to the cathode.



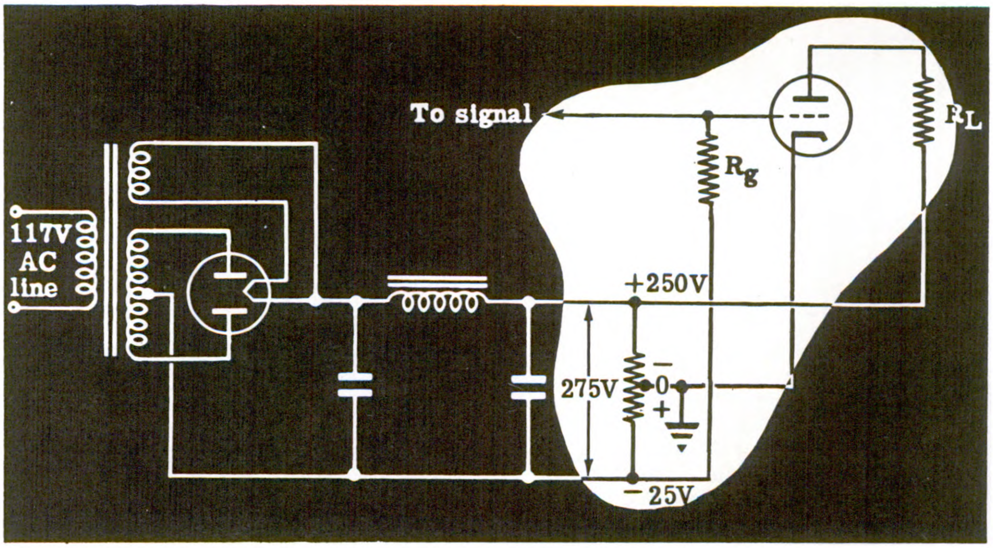
POWER SUPPLY BIAS



POWER SUPPLY BIAS--GENERATOR TYPE

B--Power Supply Bias

A negative and a positive voltage with respect to ground can be obtained from the same power supply. This is done by connecting two resistors in series across the power supply and grounding the junction of these resistors. A single tapped bleeder resistor can be used in place of the two resistors in series. The resistance to ground from the negative terminal is much smaller than the resistance from the positive terminal to ground. Therefore, the voltage across the positive portion of the bleeder will be greater than that across the negative portion. In other words, this circuit provides a large positive voltage with respect to ground which is used as the B plate supply voltage, and a small negative voltage with respect to ground which is used as grid bias voltage. The cathode is connected to ground, the plate is connected to the positive terminal of the bleeder through RL, and the grid is connected to the negative terminal of the bleeder through Rg. Therefore, the grid is made negative and the plate is made positive, with respect to the cathode.



NEGATIVE BIAS AND POSITIVE PLATE VOLTAGE FROM THE SAME POWER SUPPLY

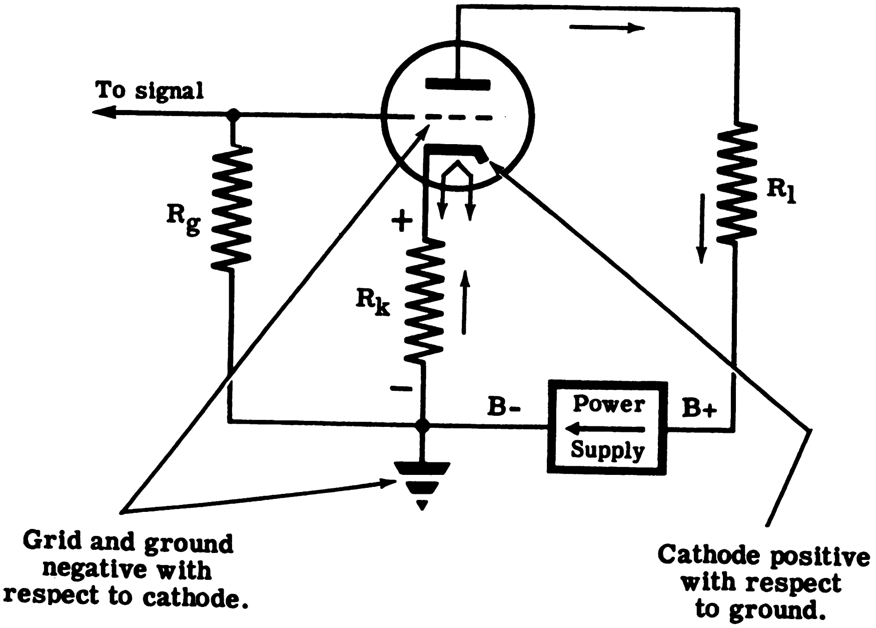
Cathode Bias

Of all bias systems, cathode bias is the most widely used. Cathode bias is obtained by connecting a resistor in series with the tube from B- or ground to the cathode.

In order to understand how this system works, it will be necessary for you to recall three points.

1. If current flows through a resistor an IR drop will be produced.
2. The end of the resistor toward which the current is flowing is the most positive (+).
3. The purpose of bias is to keep the grid negative with respect to the cathode.

Look at the following illustration. Notice that a resistor (Rk) has been placed in the cathode circuit of the vacuum tube, between cathode and ground. All the current that flows through the tube must flow up from B- through the cathode resistor. This produces an IR drop across the cathode resistor, making the cathode positive with respect to ground. Since the grid is connected to ground through Rg and ground is negative with respect to the cathode, the grid is also negative with respect to the cathode.



Grid and ground negative with respect to cathode.

Cathode positive with respect to ground.

CATHODE BIAS

SECTION VII

TOPIC 9

TETRODES AND PENTODES

A. You have learned: References:

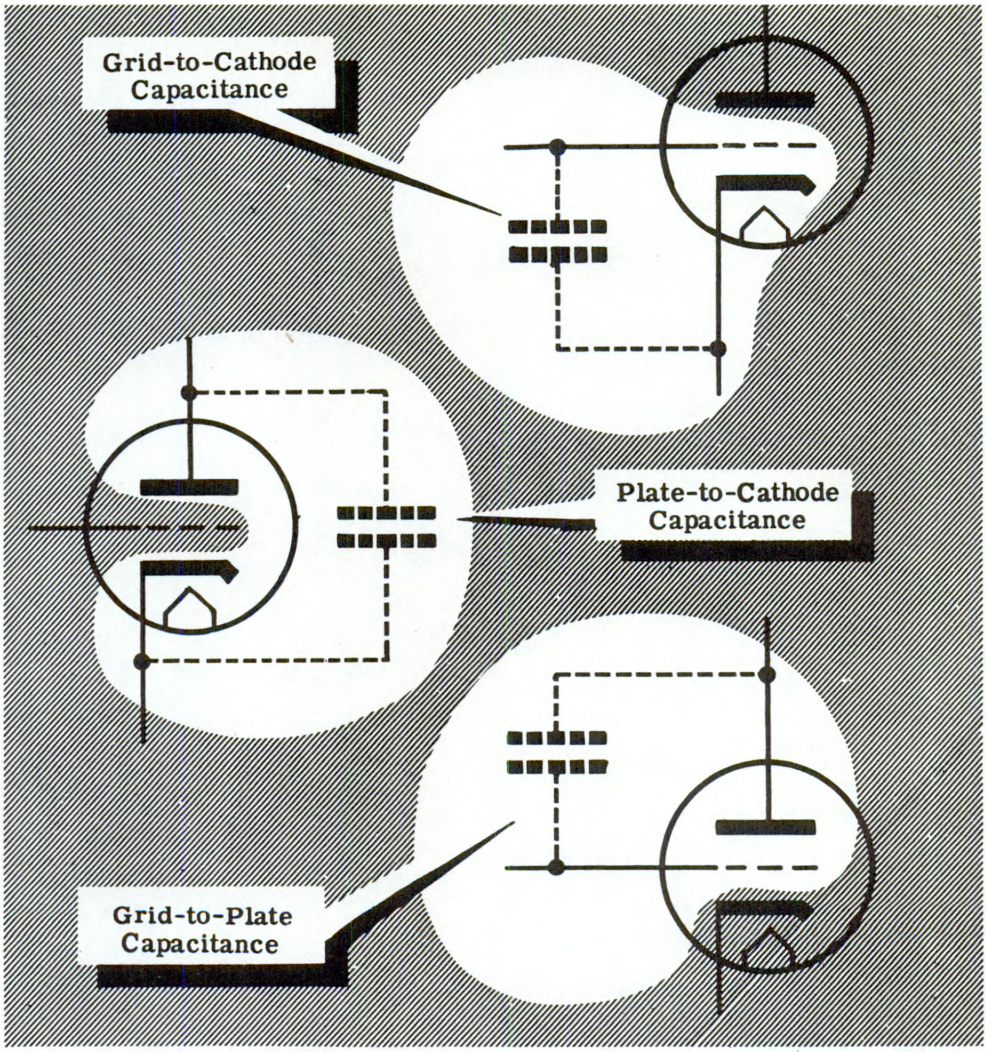
1. The uses, types, component parts and operation of rectifiers, filters, and amplifiers
2. How to troubleshoot power supplies
3. Use of the C.R.O. and tube tester
4. Construction and function of the triode
5. Tube characteristics
6. Sources and purpose of grid bias
7. Classes of amplifiers

B. You are learning:

1. The weakness of a triode	NavPers 10170, pages 395 to 396.
2. Use and construction of the tetrode and the action of the screen grid	NavPers 10170, pages 396 to 403.
3. Use and construction of the pentode and the action of the suppressor grid	NavPers 10170, pages 403 to 407.
4. Construction and operation of the variable Mu tube	NavPers 10170, pages 407 to 409.
5. Construction and operation of the beam power tube	NavPers 10170, pages 409 to 412.

WEAKNESS OF THE TRIODE

A capacitor, as you know, is nothing more than two pieces of metal separated by a dielectric (insulator). In a vacuum tube each pair of elements acts as if it were a small capacitor. In a triode there are three such capacitors--one consisting of the grid and plate, one of the grid and cathode, and the third of the plate and cathode. These are called the interelectrode capacitances and each one has a capacitance of only a few micromicrofarads.



The grid-to-plate capacitance is the one which causes most of the trouble. At high frequencies it produces undesirable effects which may prevent the tube from amplifying properly. This is known as degenerative feedback.

The tetrode was developed to reduce the interelectrode capacitance between the control grid and the plate.

USE AND CONSTRUCTION OF THE TETRODE AND ACTION OF THE SCREEN GRID

In the tetrode a second grid is placed between the control grid and the plate. Now there are two small capacitors in series between the plate and the grid and, of course, the total grid-to-plate capacitance is reduced. This second grid, called the "screen grid," has the effect of shielding the plate from the first grid and allows the tetrode to be used at higher frequencies than the triode could be used.

Normally, the screen grid has a high positive voltage and attracts electrons from the space charge just as the plate did in the triode. However, because the screen grid is a spirally wound thin wire, most of the electrons pass right through it and end up at the plate. The screen draws only a little current.

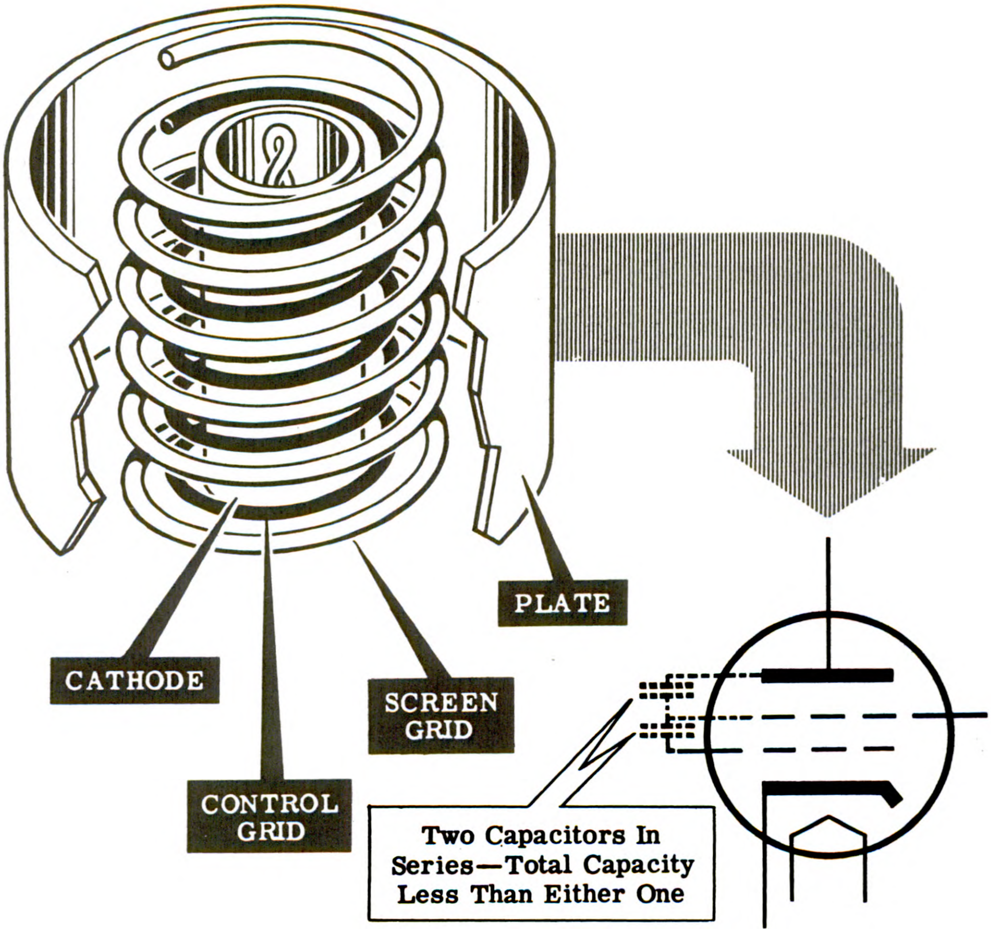


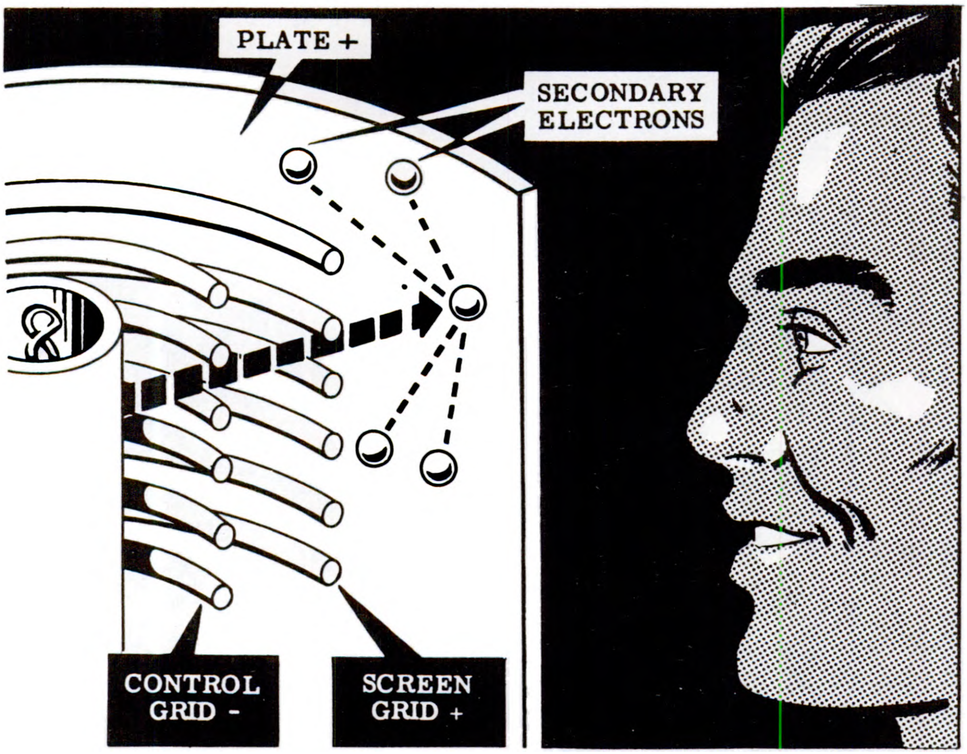
PLATE
CATHODE
SCREEN GRID
CONTROL GRID
Two Capacitors In Series—Total Capacity Less Than Either One

TETRODE

The plate is usually kept at a higher voltage than the screen and the plate circuit does not differ much from that used with triodes. In the tetrode, however, the plate voltage has less effect on the tube current than it did in the triode.

In any tube--diode, triode, or tetrode--when one electron strikes the plate, it knocks several electrons out. Known as "secondary emission," this happens because the electrons are hitting the plate at high speed which becomes even greater as the plate voltage is raised.

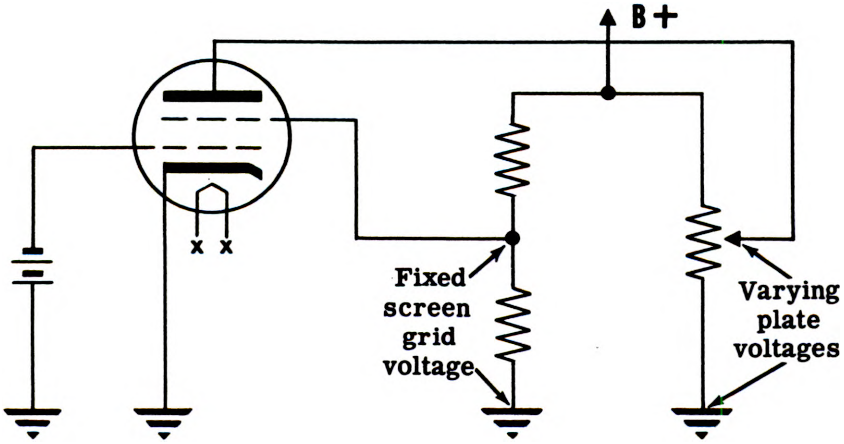
In the triode, secondary emission is not important since the plate is the most positive element in the tube and, therefore, attracts all the electrons that have been knocked out of it. In the tetrode, however, some of these secondary electrons (those which have been freed from the plate as a result of secondary emission) are attracted to the screen. Any flow of secondary electrons from the plate to the screen adds to the screen current and subtracts from the plate current.



CUTAWAY SECTION--OF A TETRODE

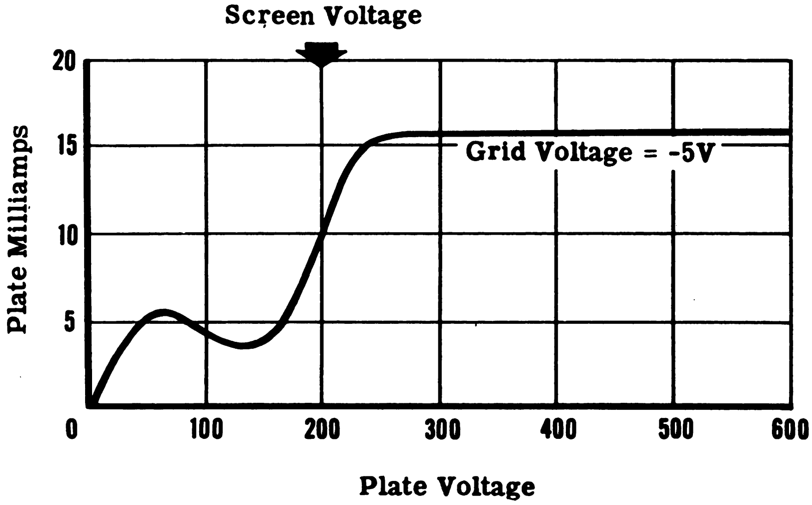
The number of secondary electrons which do not return to the plate depends upon the difference between the plate and the screen voltages. If the plate voltage is much higher than the screen's, all the secondary electrons will return to the plate and there will be no decrease in plate current. If the plate voltage is much lower than the screen's, fewer secondary electrons will be emitted, but all of these will be attracted to the screen.

The tetrode is rarely used today, and you are being told about this tube only because it is a "stepping stone" between the triode and the pentode. If static characteristics of a tetrode were taken with varying plate voltage but constant control and screen grid voltages, you would get a curve resembling the one in the diagram.



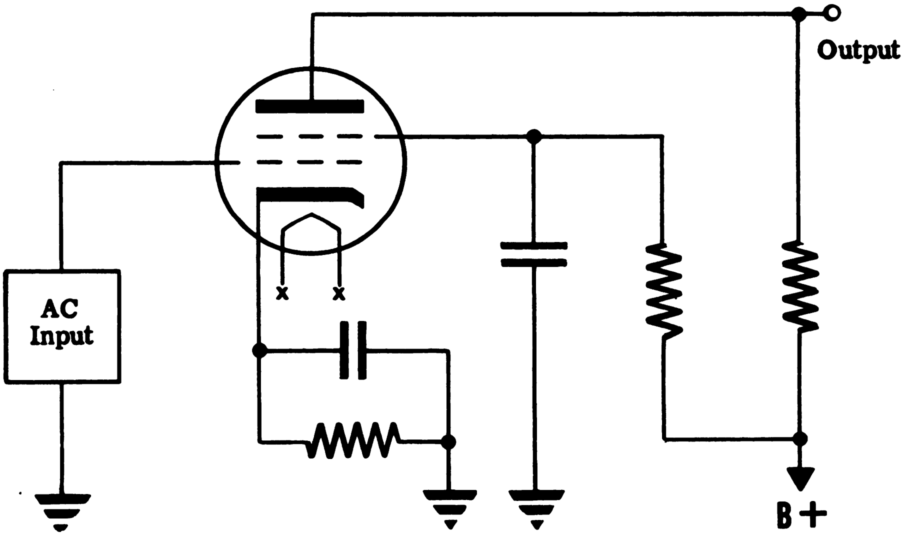
Notice that at high plate voltages above 300V, the plate current does not change when the plate voltage is increased. This is because the screen shields the plate from the space charge at the cathode, which causes the screen to exert a greater control over plate current than the plate itself.

At about 100 volts, an increase in plate voltage causes a decrease in plate current because more electrons are knocked out of the plate by secondary emission. As long as the plate voltage is below the screen voltage, almost all the secondary electrons go to the screen.

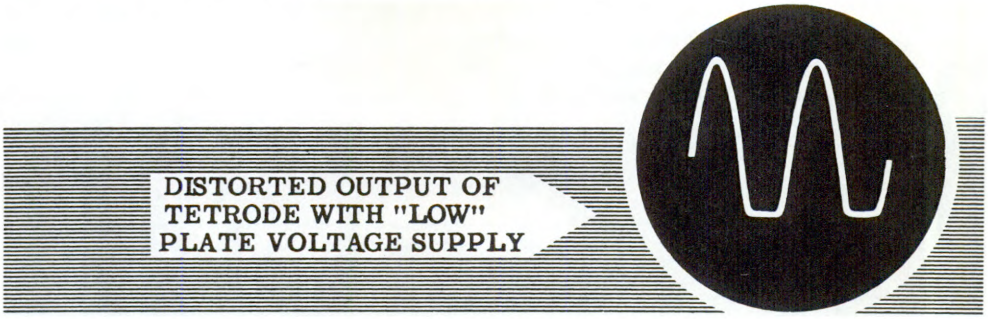


Cathode bias in the tetrode is obtained in the same way as in the triode, except that in the tetrode the current flowing through the cathode resistor is the sum of the screen and plate current.

The control grid voltage varies according to the input signal and produces variations in the plate current. Therefore the plate current and the screen grid current vary with the control grid voltage. Screen grid voltage variation is prevented by connecting a screen bypass capacitor to ground. This keeps the screen at a fixed d-c level and the tube current will be varied only by varying the control grid voltage.



With a-c on the control grid of the tube, the plate voltage will vary because of the drop in the load resistor just as in the triode. When the tetrode is used for getting large amplifications, the plate voltage varies over a wide range and, if it drops below the screen grid voltage, secondary emission effects cause distortion in the output.



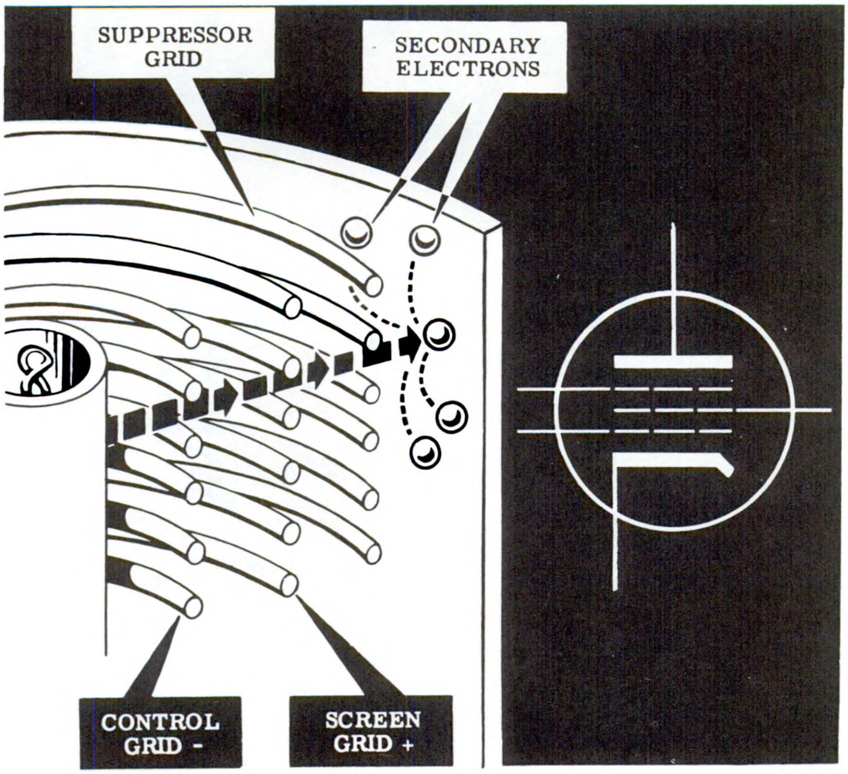
To prevent this, the plate voltage would have to be very large to keep the plate at a higher potential than the screen regardless of the amount of voltage variation at the plate.

This the requirement of an abnormally high B----, is the main disadvantage of using a tetrode. You will see how the pentode overcomes this disadvantage in your next experiment.

USE AND CONSTRUCTION OF THE PENTODE AND ACTION OF THE SUPPRESSOR GRID

You have seen that the main disadvantage of the tetrode is the need for a high plate voltage to prevent distortion in its output due to the effect of secondary emission.

The pentode is designed to overcome this undesirable feature of the tetrode by eliminating the flow of secondary electrons between the plate and the screen grid. This is accomplished by the inclusion of a third grid, the suppressor grid, between the plate and the screen grid.



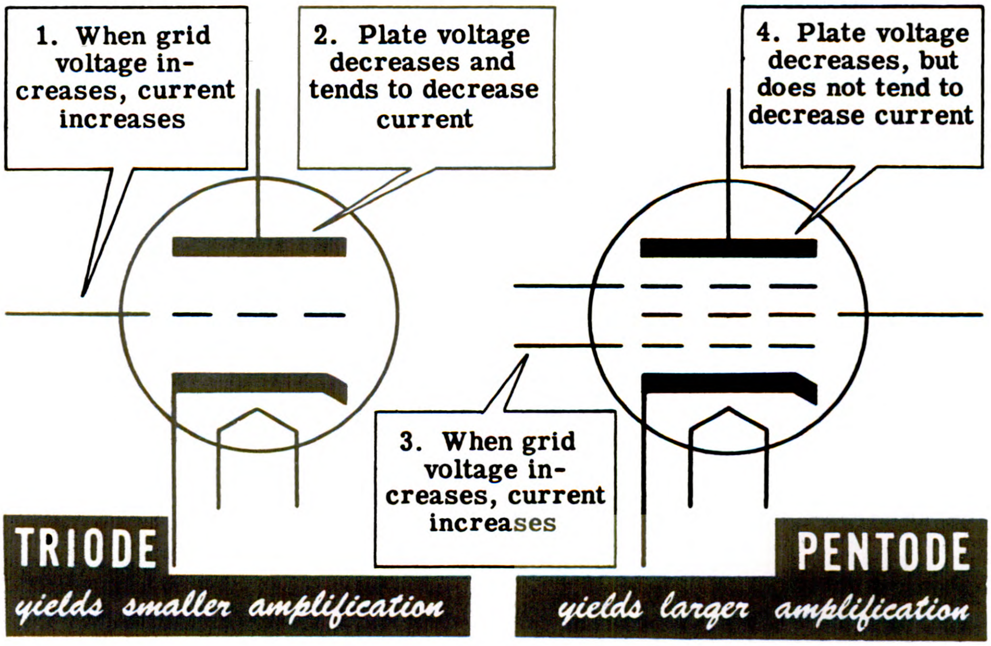
The suppressor grid is usually kept at cathode potential so that it is always very negative with respect to the plate. Therefore, any electron that is in the region between the suppressor and the plate (such as a secondary electron) is attracted back to the plate and prevented from getting through the suppressor to the screen. As a result of this arrangement, secondary emission does not affect the operation of the pentode.

You remember that in a triode a decrease of the negative grid voltage produced an increase in the current and a decrease in the plate voltage. The plate voltage change was more than the change in grid voltage. We called the ratio of plate voltage change to grid voltage change "amplification."

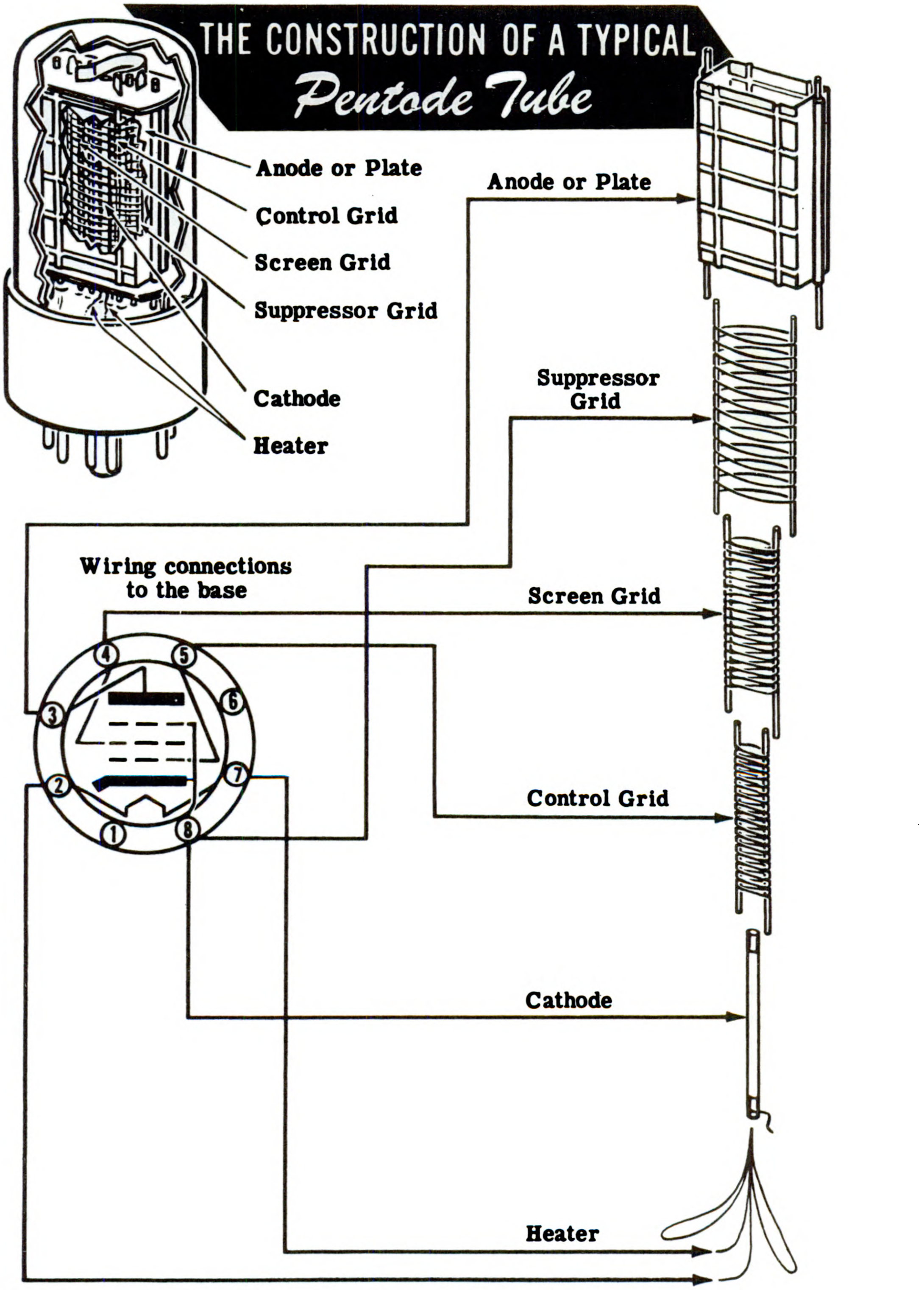
You remember too that the plate voltage in a triode also affects the current flow. The decrease in plate voltage has a tendency to decrease the current. The grid is trying to increase the current. It is clear, then, that the decrease in plate voltage is opposing the effect of the grid voltage decrease.

If the grid has 20 times as much control of the current as the plate has, the limit of amplification will be 20. When such an amplification is reached, the plate voltage changes will be 20 times as large as the grid voltage changes and, theoretically, there will be no change in the current. Thus, the amplification is limited by the fact that the plate has some effect on the current.

In a pentode, neither the suppressor nor the plate voltage affect the amount of current drawn from the space charge surrounding the cathode since the screen grid shields both of these elements from the cathode. As in the tetrode, the pentode's screen voltage is fixed at some positive value and, therefore, only the variations of control grid voltage cause changes in plate current.


1. When grid voltage increases, current increases
2. Plate voltage decreases and tends to decrease current
4. Plate voltage decreases, but does not tend to decrease current
3. When grid voltage increases, current increases
TRIODE
yields smaller amplification
PENTODE
yields larger amplification

In the pentode the plate voltage can very considerably with almost no effect on the current and, therefore, with no cancellation of the grid's control of the plate current. As a result, the amplification of a pentode is many times greater than that of a triode.

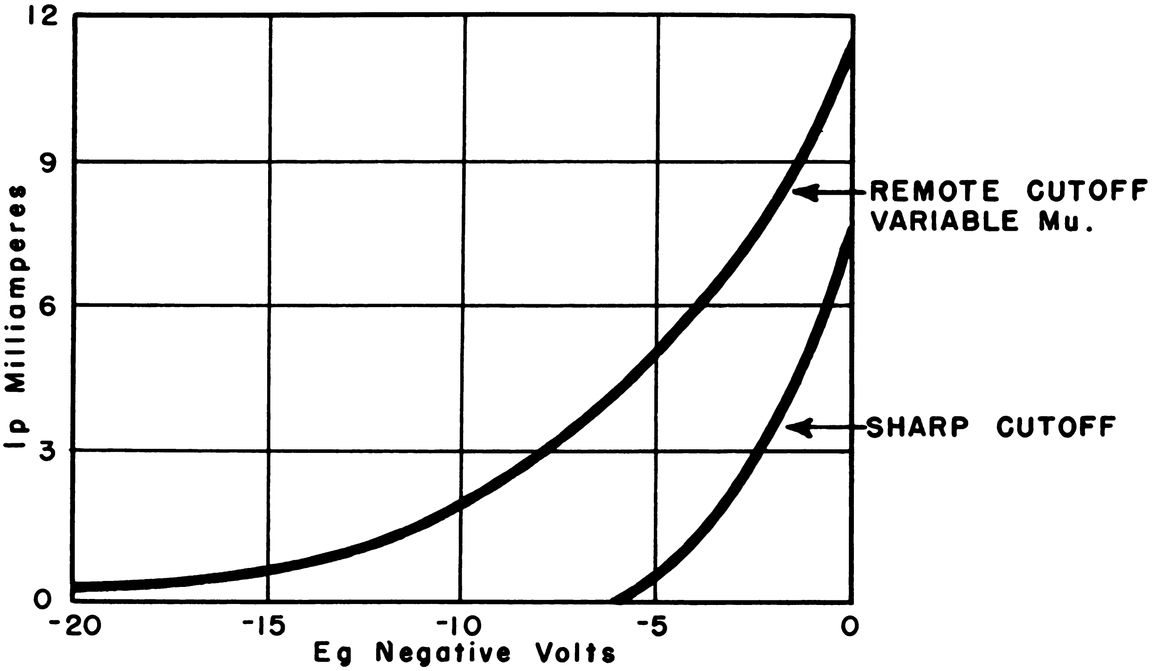


CONSTRUCTION AND OPERATION OF THE VARIABLE Mu TUBE

Variable Mu means a changing amplification factor. Variable Mu tubes are usually pentodes. But, they're pentodes with a control grid which has the wires unequally spaced--spaced wide at the middle and close at the ends.

The unequal spacing of the grid wires is the reason for the variable amplification factor. Here is how it works. A small negative grid voltage cuts off Ip at the close-spaced grid wires. Then as Eq becomes more negative, the medium-spaced grid wires cut off the Ip. But the Eq must be a very strong negative voltage to cut off Ip at the wide-spaced grid wires.

You can see this gradual cut-off in the Eq-Ip curves of the following figure. The gradual cut-off variable Mu tube is compared to the sharp cut-off regular Mu tube.



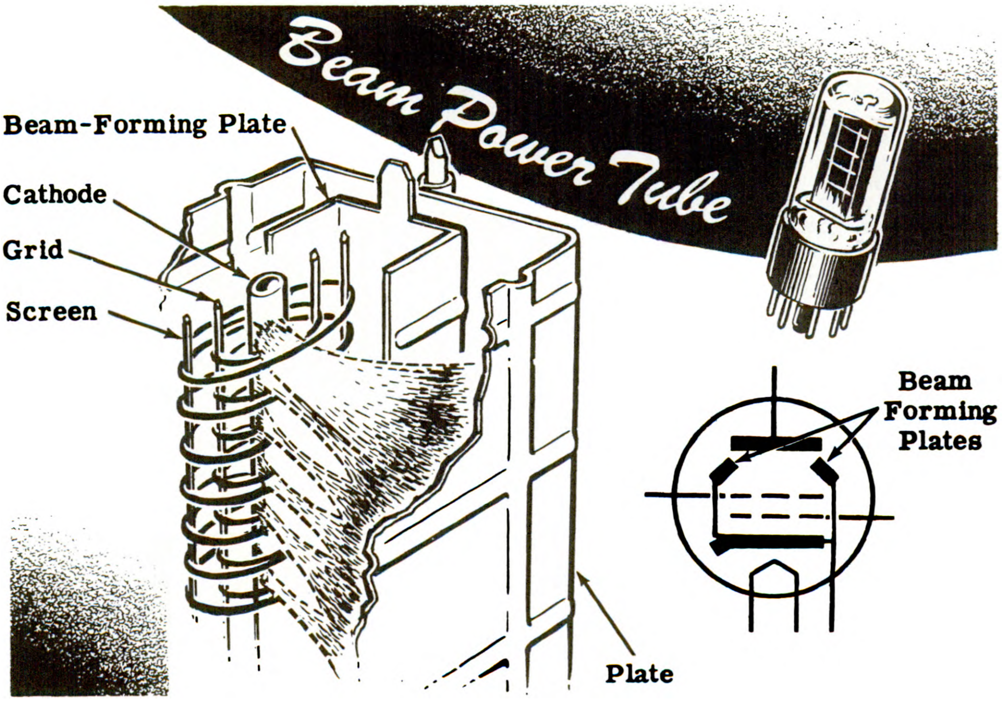
CONSTRUCTION AND OPERATION OF THE BEAM POWER TUBE

You have learned from your study of the pentode that the suppressor grid reduces the effects of secondary emission. Instead of using the suppressor grid to control secondary emission from the plate, the same effect can be obtained by arranging the tube elements in such a way as to produce a negative charge near the plate. The action of this space charge is to repel any secondary emitted electrons back to the plate just as the suppressor does in the pentode.

The figure below shows the internal structure of a typical beam power tube such as the 6L6, 50L6, 6V6, and others. You see that this tube has a cathode, control grid, screen grid, and two new parts--the beam-forming plates which are connected to the cathode. Each beam-forming plate extends about one-fourth the distance around the grids of the tube and prevents any electrons from reaching the plate except through the openings between the beam-forming plates. This tends to concentrate the electron stream into a small area and thereby form an electron beam.

The openings in the grids are arranged in such a way that the electrons pass between the grid wires in layers or sheets. After passing the screen grid, these electrons combine to form a concentration of electrons, or space charge, near the plate. It is this space charge that does the same job as the suppressor in the pentode.

The beam power tube has an advantage over the pentode in that a greater power output. can be obtained for a given amount of cathode emission.



JOB SHEET NO. 33

1. The screen grid decreases ______________________________ and ______________________________.

2. The screen grid voltage is lowered to the proper value by ______________________________.

3. The screen grid potential is held constant by ______________________________.

4. The suppressor grid suppresses ______________________________.

5. The suppressor is connected to ______________________________ or ______________________________.

SECTION VII

TOPIC 10

PUSH-PULL CIRCUITS

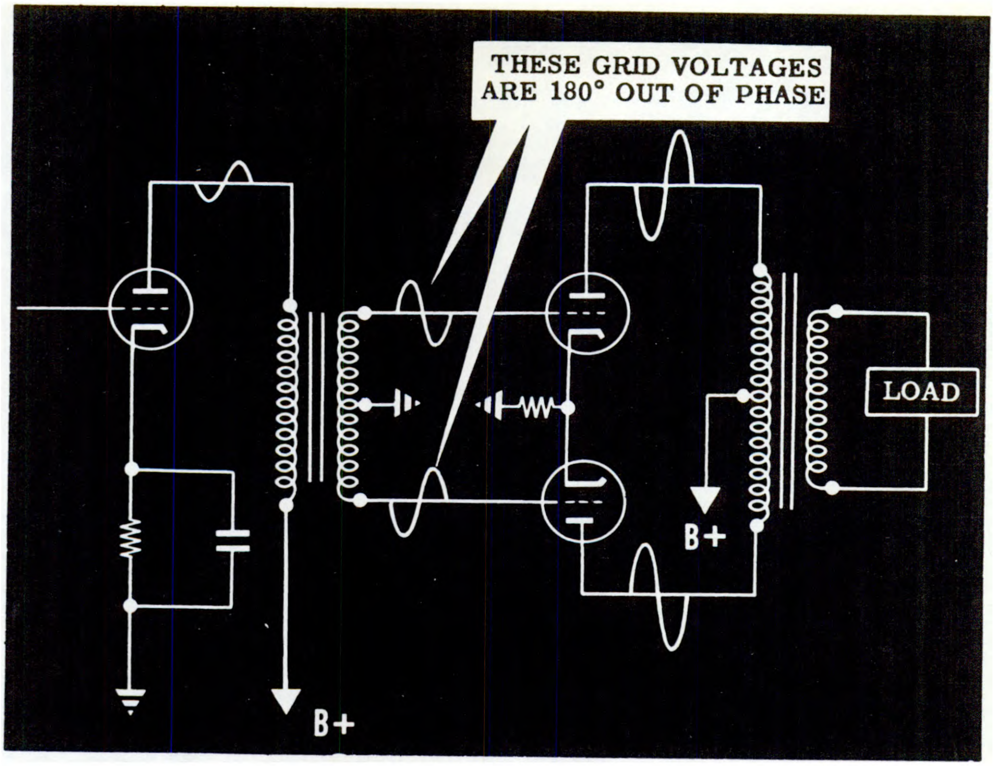
A. You have learned:	References:
1. Uses, types, component parts, and operation of rectifiers, filters, and amplifiers	
2. How to troubleshoot power supplies with the aid of the C.R.O. and tube tester	
3. Construction, function, and characteristics of the triode	
4. Classes of amplifiers	
5. Use, construction, and operation of the tetrode, pentode, variable Mu tube, and beam power tube	
B. You are learning:	
1. How the push-pull amplifier works	NavPers 10171, pages 26 to 42
2. The classes of push-pull	NavPers 10171, pages 29 to 30

HOW THE PUSH-PULL AMPLIFIER WORKS

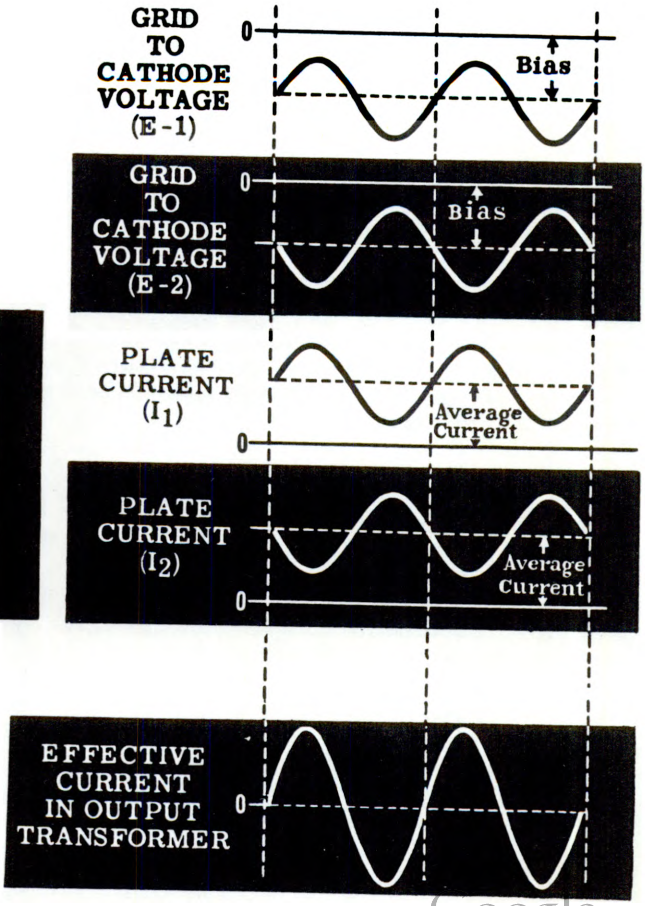
In this topic, you will see that a very good type of power amplifier can be made by using a push-pull system. A power amplifier can be made by using only one tube, but when you want to double the power, it is often more convenient to use two power tubes, rather than use one very large power tube. The obvious way to use two tubes would be to connect the two grids together and the two plates together (parallel connection) and thereby double the power output. However, there is a way that is better--that is to connect the tubes in push-pull. In a push-pull amplifier, the input voltages to the grids of the two tubes are 180 degrees out of phase. This phase difference is often achieved by putting the signal into the primary of a transformer with a center-tapped secondary--the two grids are connected to the opposite ends of the secondary and the center tap is grounded or connected to a source of grid bias voltage.

The plates are connected to opposite ends of the primary winding of an output transformer and the center tap is connected to B+. The final output voltage appears across the output transformer secondary which is connected to the load.

In a typical push-pull amplifier, the grids receive a-c voltages from opposite terminals of a transformer secondary winding. The transformer secondary is center tapped and the center tap is connected to ground. The a-c grid voltages are 180 degrees out of phase. When one grid becomes less negative, the other grid becomes more negative by the same amount. The sum of the tube currents does not vary but remains pure d-c since, when one current is increasing, the other is decreasing by the same amount. Because the sum of



A TYPICAL PUSH-PULL CIRCUIT



NORMAL WAVE FORMS FROM A PUSH-PULL AMPLIFIER the two currents is pure d-c, no bypass capacitor is needed across the cathode bias resistor.

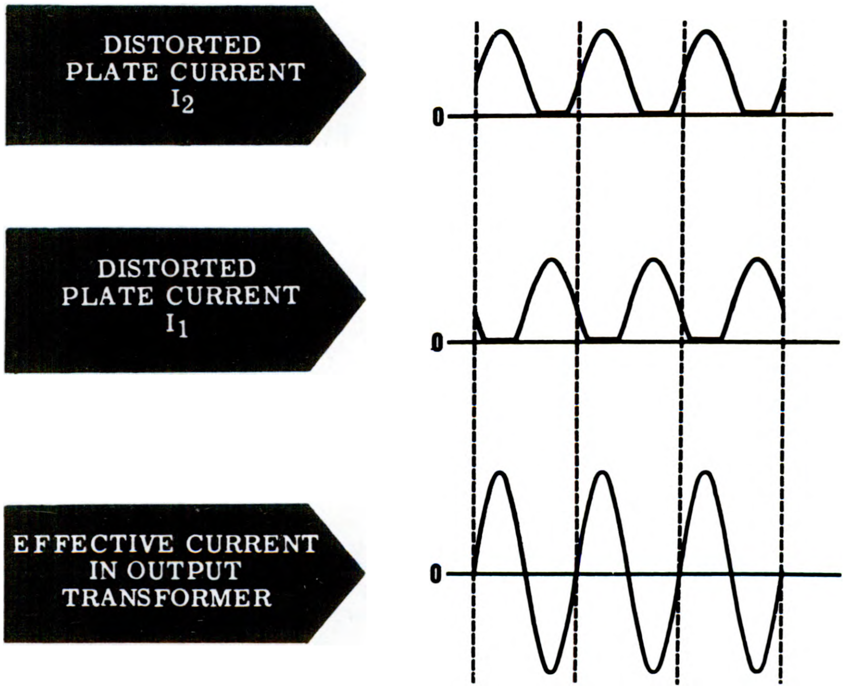
In the output transformer, it is the difference between the two currents that is the output signal. The greater the signal input, the greater this difference and the greater the output.

On the preceding sheet you see a set of typical waveforms taken from a push-pull amplifier which is working normally.

Up to now, the only advantage of the push-pull circuit that has been mentioned has been the fact that no bypass capacitor is needed since the voltage variations produced across the cathode resistor by the out-of-phase plate current will cancel each other. If this were the only advantage of the push-pull circuit over the use of two tubes connected in parallel, the parallel combination would be more common than it is. Actually, there are some very important advantages which make the use of the push-pull circuit more preferable.

Consider what happens if the two tubes in parallel are driven into cut-off by a large signal output. Both tubes go into cut-off together and distortion appears in the output. If the tubes are connected in a push-pull arrangement, one tube will be driven into cut-off on one half-cycle and the other tube on the next half-cycle. In the output, the distortion is minimized, as you can see from the waveforms below.

DISTORTED WAVE FORMS
DUE TO CUT-OFF


DISTORTED PLATE CURRENT I_2
0
DISTORTED PLATE CURRENT I_1
0
EFFECTIVE CURRENT IN OUTPUT TRANSFORMER
0

The big advantage of the push-pull circuit reducing distortion is that the tubes can be intentionally overdriven to produce a larger output, and the output still will be practically undistorted.

CLASSES OF PUSH-PULL

Class A is biased at the mid-point of the operating range of the tubes and gives the least distortion of all the classes. Class B is biased so that the plate current will flow for a little more than half of each signal cycle. It has a higher power output than Class A, but more distortion. Class AB is biased so that the plate current flows for about three-quarters of each signal cycle. It combines the small-distortion features of Class A with the high-power features of Class B.

JOB SHEET NO. 34

1. Maximum power is delivered when the load impedance is equal to ____________________.
2. The impedance is transformed to the value required by the output tubes by

   ____________________________________.
3. The disadvantages of single-ended power amplifier stages are ____________________

   and ____________________________________.
4. The advantages of a push-pull power stage are ____________________________________

   and ____________________________________.
5. The signals on the two push-pull grids are ____________________________________.

SECTION VIII

HAND TOOLS

Topic No.	Topic Title	Sheet
1.	General Purpose Tools	VIII-1-1
2.	Wrenches	VIII-2-1
3.	Metal-Cutting Tools	VIII-3-1
4.	Metal Fasteners	VIII-4-1
5.	Soldering	VIII-5-1
6.	Measuring Tools	VIII-6-1
7.	Miscellaneous Tools	VIII-7-1

SECTION VIII

TOPIC 1

GENERAL PURPOSE TOOLS

A. You have learned:

References:

1. About Fire Control in general
2. About d-c and a-c circuits
3. About safety precautions
4. About electrical machinery
5. About basic electronics

B. You are learning:

1. What Section VIII contains
2. Use, types, and correct application of general-purpose hand tools.
3. To identify each general-purpose tool.

NavPers 10623-A, pages 5 to 20

INTRODUCTION TO SECTION VIII

Topic 1 covers the use, types, and correct application of the general-purpose tools.
The types, use, and correct application of wrenches is covered in Topic 2.
In Topic 3 the metal-cutting tools are discussed.
The types and uses of metal fasteners are covered in Topic 4.
Topic 5 covers the soldering tools and their proper use.
The measuring tools are covered in Topic 6.
The use and application of other miscellaneous tools is covered in Topic 7.
The general-purpose tools that will be taken up in this topic are: (1) screw drivers, (2) pliers, (3) hammers, (4) punches, and (5) vises.

SCREW DRIVERS

Use: ______________________________

Types

1. General-purpose; standard; common
   a. Used with ______________________________
2. Phillips
   a. Used with ______________________________
3. Offset
   a. Used ______________________________
4. Jewelers
   a. Used ______________________________

Parts of screw drivers

1. ____________________
2. ____________________
3. ____________________

Rules for proper application of screw drivers

1. ____________________
2. ____________________
3. ____________________
   ____
4. ____________________
   ____
5. ____________________
   ____

PLIERS

Use: ____________________
____

Types

1. Combination or Slip-joint
   a. Used to ____________________
   ____
2. Long nose
   a. Used to ____________________
   ____
3. Round jaw
   a. Used to ____________________
   ____
4. Side cutters
   a. Used to ____________________
   ____

5. Diagonal cutters
   a. Used to ______________________________

Parts of pliers

1. ______________________________
2. ______________________________

Rules for proper application of pliers

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

HAMMERS

Use: ______________________________

Types

1. Ball-peen
   a. Used to ______________________________
2. Soft-faced
   a. Used to ______________________________
3. Mallets
   a. Types of mallets
      (1.) ______________________________
      (2.) ______________________________
      (3.) ______________________________
   b. Used to ______________________________

Parts of hammers

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Rules for proper application of hammers

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________

PUNCHES

Use: ____________________

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Types

1. Starting punch
   a. Used to ____________________
   ____
2. Drifts punch
   a. Used to ____________________
   ____
3. Aligning punch
   a. Used to ____________________
   ____

4. Center punch
   a. Used to ______________________________

   ____

5. Prick punch
   a. Used to ______________________________

   ____

6. Gasket punch
   a. Used to ______________________________

   ____

Parts of punches

1. ______________________________
2. ______________________________

Rules for proper application of punches

1. ______________________________

   ____

2. ______________________________

   ____

3. ______________________________
4. ______________________________

VISES

Use: ______________________________

Types

1. Machinist vise
   a. Used to ______________________________

   ____

2. Utility vise
   a. Used to ______________________________

   ____

3. Pipe vise
   a. Used to ______________________________

   ____

Parts of vises

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

Rules for proper application of vises

1. ____
2. ____
3. ____
____
4. ____
____

SECTION VIII

TOPIC 2

WRENCHES

A. You have learned:	References:
1. About Fire Control in general	
2. About d-c and a-c circuits	
3. About safety precautions	
4. About electrical machinery	
5. About basic electronics	
6. About general-purpose tools	
B. You are learning:	
1. Types of common wrenches	NavPers 101623-A, pages 21 to 34
2. Use of the various wrenches	
3. How and when to apply the various wrenches	
4. How to identify the various wrenches.	

TYPES OF WRENCHES

Types of wrenches that are discussed in this topic are:

1. Open-end wrench
2. Box-end wrench
3. Socket wrench
4. Adjustable wrench
5. Spanner wrench
6. Special wrenches:
    a. Dial adjustment wrench
    b. Allen wrench
    c. Spintite

Generally speaking, wrenches are used to exert a twisting strain, or turning force, on bolt heads, nuts, and studs.

OPEN-END WRENCHES

Construction: ____

____

____

WRENCHES

Use: ____________________

____

____

BOX-END WRENCHES

Construction: ____________________

____

____

Use: ____________________

____

____

Advantages: ____________________

____

____

____

Disadvantages: ____________________

____

____

SOCKET WRENCH

Types

1. Socket wrenches
2. Socket-head wrenches

Construction: ____________________

____

____

____

Uses: ____________________

____

____

Socket wrench sets include

1. ____________________

2.

3.

4.

5.

6.

ADJUSTABLE WRENCH

Construction:

Use:

Disadvantage:

SPANNER WRENCH

Types

1. Hook spanner
2. Adjustable hook spanner
3. Pin spanner
4. Face pin spanner

Construction

1. Hook spanner:

2. Adjustable hook spanner:

3. Pin spanner: ____________________

4. Face pin spanner: ____________________

Use

1. Hook spanner: ____________________

2. Adjustable hook spanner: ____________________

3. Pin spanner: ____________________

4. Face pin spanner: ____________________

SPECIAL WRENCHES

Dial adjustment wrench

1. Construction: ____________________

2. Use: ____________________

Allen-type wrench

1. Construction: ____________________

2. Use: ____________________

Spintite wrench

1. Construction:____
____
____

2. Use:____
____
____

Rules for proper application of wrenches

1.____
2.____
3.____
4.____
5.____
6.____
7.____

SECTION VIII

TOPIC 3

METAL-CUTTING TOOLS

A. You have learned:

1. About Fire Control in general
2. About d-c and a-c circuits
3. About safety precautions
4. About electrical machinery
5. About basic electronics
6. About general-purpose tools
7. About wrenches

B. You are learning:

1. The name, identification, use, type, and rules of application concerning the following metal-cutting tools:

	References:
a. Drills and bits	NavPers 10085, pages 186-194 NavPers 10623-A, pages 57-70
b. Hacksaws	NavPers 10085, pages 226-230 NavPers 10623-A, pages 38-44
c. Files and file cards	NavPers 10085, pages 238-243 NavPers 10623-A, pages 48-56
d. Chisels	NavPers 10085, pages 161-173 NavPers 10623-A, pages 44-48
e. Reamers	NavPers 10085, pages 245-249 NavPers 10623-A, pages 72-73
f. Countersinks and counterbores	NavPers 10623-A, pages 70-71
g. Taps and dies	NavPers 10623-A, pages 75-88 NavPers 10085, pages 203-210

DRILLS AND BITS

Use: ____

Common hand tools for holding and turning drills are

1. ______________________________
2. ______________________________
3. ______________________________

The two types of twist drills are:

1. ______________________
2. ______________________

The parts of a twist drill are

1. Shank
2. Body
    a. ______________________
    b. ______________________
    c. ______________________

The types of shanks a twist drill may have are

1. ______________________
2. ______________________
3. ______________________

Rules for proper application of drills

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________

HACKSAW

Use: ______________________

The parts of a common hacksaw are

1. ______________________
2. ______________________
3. ______________________

The types of hacksaw blades are

1. ______________________________

    a. Best for sawing brass, tool steel, cast iron, rails, and heavy cross-section stock.

2. ______________________________

    a. Usually best for sawing hollow shapes and metals having a light cross-section.

Selecting the best blade for a job is a question of finding one the right type and pitch.

The PITCH of a blade indicates the number of "teeth" it has per inch. Pitches of 14 18, 24, and 32 are available.

A blade with a pitch of 14 teeth/inch should be used on ______________________________

____

The 18-pitch blade should be used on ______________________________

____

The 24-pitch blade should be used on ______________________________

____

The 32-pitch blade should be used on ______________________________

____

The blade is properly mounted in the frame when the teeth point ______________

____

Rules for proper application of hacksaws

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____

FILES AND FILE CARDS

Use of files: ____

____

Use of file cards: ____

____

Files are classified according to their SHAPE, CUT, AND GRADE.

File shapes

1. Square files
   - a. Appearance: ______
   - b. Use: ______
2. Flat files
   - a. Appearance: ______
   - b. Use: ______
3. Round files
   - a. Appearance: ______
   - b. Use: ______
4. Half-round files
   - a. Appearance: ______
   - b. Use: ______
5. Triangular files
   - a. Appearance: ______
   - b. Use: ______
6. Mill files
   - a. Appearance: ______
   - b. Use: ______

7. "Swiss Pattern" files

   a. Appearance: ______________________________

   ____

   b. Use: ______________________________

   ____

File cuts

1. ______________________________

   a. Use: ______________________________

   ____

2. ______________________________

   a. Use: ______________________________

   ____

File grades

1. Rough
2. Bastard
3. Second cut
4. Smooth
5. Dead smooth

Rules for application of files

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

CHISELS

Use: ______________________________

____

Types

1. Cold chisel

   a. Use ______________________________

   ____

2. Cape chisel

   a. Use ______________________________

   ____

3. Side-cutting chisel

   a. Use ______________________________

   ____

4. Diamond-point chisel

   a. Use ______________________________

   ____

5. Round-nose chisel

   a. Use ______________________________

   ____

Rules of application of chisels

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

REAMERS

Use: ______________________________

Types

1. Straight flute reamer
2. Spiral flute reamer
3. Expansion reamer
4. Taper reamer

Rules for application of reamers

1. ______________________________
2. ______________________________

3. ______

4. ______

COUNTERSINKS AND COUNTER BORES

Use

1. Countersinks: ______
2. Counterbores: ______

Types

1. ______
2. ______
3. ______
4. ______

Rules for application

1. ______
2. ______
3. ______

TAPS AND DIES

Use

1. Taps: ______
2. Dies: ______

Types of Taps

1. Taper
   a. Used to ______
2. Plug
   a. Used to ______

3. Bottoming

   a. Used to ________________________________

   ____

Types of Dies

1. ________________________________

2. ________________________________

3. ________________________________

4. ________________________________

Rules for application of taps and dies

1. ________________________________

2. ________________________________

3. ________________________________

4. ________________________________

5. ________________________________

6. ________________________________

7. ________________________________

SECTION VIII

TOPIC 4

METAL FASTENERS

A. You have learned: References:

1. About fire control in general
2. About d-c and a-c circuits
3. About safety precautions
4. About electrical machinery
5. About basic electronics
6. About general-purpose tools
7. About wrenches
8. About metal-cutting tools

B. You are learning:

1. The name, identification of, use, type, and rules of application concerning the following metal fasteners:

a. Machine screws	NavPers 10623-A, pages 89 to 92
b. Machine bolts	NavPers 10623-A, pages 92 to 93
c. Nuts and washers	NavPers 10623-A, pages 96 to 97
d. Studs	NavPers 10623-A, page 95
e. Keys, pins, and dowels	NavPers 10085, pages 245 to 247
f. Set screws	NavPers 10623-A, pages 99 to 100
	NavPers 10623-A, pages 95 to 96

MACHINE SCREWS

Machine screws are classified according to the type of head on the screw. Common types of machine screws are

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

The complete description of a machine screw must include

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Machine screws are used

1. In tapped hole for ______________________________
____

2. With nuts for ______________________________
____

The machine screw and tapped hole must have the same ______________________________
____

Machine screws are driven with a ______________________________ or
____

MACHINE BOLTS

Types: ______________________________
____

Uses: ______________________________
____

Rules for proper application of machine bolts

1. ______________________________

2. ______________________________

WASHERS

Types

1. ______________________________

2. ______________________________

3. ______________________________

Uses

1. ______________________________

2. ______________________________

3. ______________________________

Rules for proper application of washers

1. ____________________
2. ____________________

____

NUTS

Types of Nuts and their uses are

1. Square nuts
    a. Use: ____________________
2. Hexagonal nuts
    a. Use: ____________________
3. Jam nuts
    a. Use: ____________________
    ____
4. Castellated nuts
    a. Use: ____________________
    ____
5. Wing nuts
    a. Use: ____________________
6. Cap, or "acorn," nuts
    a. Use: ____________________
    ____
7. Thumb nuts
    a. Use: ____________________
8. Elastic stop nuts
    a. Use ____________________
    ____

Rules for proper application of nuts

1. ____________________
2. ____________________
3. ____________________

STUDS

Both ends of studs are threaded

1. One end is screwed into ____________________
2. Other end takes ____________________

Use of studs: ____________________

____

KEYS, PINS, AND DOWELS

Types of Keys, Pins, and Dowels and their uses are

1. Cotter keys
   a. Use: ____________________

   ____
2. Square keys
   a. Use: ____________________

   ____
3. Woodruff keys
   a. Use: Same as square key.
4. Taper pins
   a. Uses: 1. ____________________

   2. ____________________
5. Dowel pins
   a. Use: ____________________

   ____

Rules for proper application

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

SETSCREWS

Types

1. ____________________
2. ____________________
3. ____________________

Uses

1. ____
2. ____

Rules for proper application

1. ____
2. ____
3. ____

SECTION VIII

Topic 5

SOLDERING

A. You have learned:

References:

1. About Fire Control in General
2. About d-c and a-c Circuits
3. About Safety Precautions
4. About Electrical Machinery
5. About Basic Electronics
6. About General-Purpose Tools
7. About Wrenches
8. About Metal-Cutting Tools
9. About Metal Fasteners.

B. You are learning:

1. About Solder	NavPers 10623-A, pages 123 to 124
2. About Soldering Coppers	NavPers 10623-A, pages 124 to 127
3. About Flux	NavPers 10623-A, pages 127 to 128
4. How to "Tin" a soldering copper	NavPers 10623-A, pages 128 to 130
5. How to Solder	NavPers 10623-A, pages 130 to 134

SOLDER

1. Solder is used to:

    a. Join pieces of metal
    b. Make metal joints and seams leak proof
    c. Join electrical wires so they will be good conductors

2. There are two types of solder:

    a. Soft solder

        (1) Usually consists of ______________________________

        (2) Manufactured in both ______________________________ forms.

        (3) Mostly used on ______________________________

        (4) Should never be used where heavy strains and stresses will be applied to the soldered parts.

    b. Hard solder

        (1) Made of alloys of ______________________________

        (2) Much stronger than soft solders.

        (3) Will withstand considerable strain, pressure, and vibration.

SOLDERING COPPERS

1. Soldering coppers are tools used to apply heat to metal that is being soldered.
2. There are two types of soldering tools used by FT's:
    a. Electrical soldering coppers
        (1) Interchangeable tips
        (2) Used for light work
    b. Electrical soldering guns
        (1) Usually have two heats
        (2) Most are provided with interchangeable tips
        (3) Provide heat quickly for extremely small work surfaces

FLUXES

1. "Flux" is a chemical preparation (powder, paste, or liquid) used to ____________

____

____

2. Wire solders may have acid or rosin core fluxes.
    a. On fire control equipment use only ____________________ flux.
3. Paste flux

____

TINNING A SOLDERING COPPER

Soldering coppers must be "tinned" before they will do a good job of soldering. "Tinning" is the process by which the copper point is coated with solder to prevent oxidation of the copper when heated.

The five steps to properly "tin" a soldering copper

1. ____

____

2. ____

____

3. ____

____

4. ____

____

5. Reheat the copper and it's ready to use.

SOLDERING PROCEDURE

The proper procedure for soldering two pieces of metal

1. Clean the surfaces to be soldered.
2. Use a well-tinned copper.
3. Use the proper flux.
4. Control the heat.
5. Keep soldered surfaces close together.
6. Preheat the metal by keeping the copper flat on the work.
7. Apply solder to the metal, not to the copper.
8. Don't handle solder job until it has set.

Proper procedure for soldering electrical connections

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________

Proper procedure for "sweat" soldering

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

SECTION VIII

TOPIC 6

MEASURING TOOLS

A. You have learned: References:

1. About Fire Control in General
2. About d-c and a-c Circuits
3. About Safety Precautions
4. About Electrical Machinery
5. About Basic Electronics
6. About General-Purpose Tools
7. About Wrenches
8. About Metal-Cutting Tools
9. About Metal Fasteners
10. About Soldering

B. You are learning:

1. What measuring, marking and testing is.
2. The identification and use of the following measuring and marking tools:

a. Steel rule	NavPers 10623-A, pages 141 to 144
b. Calipers	NavPers 10623-A, pages 172 to 174
c. Feeler gage	NavPers 10623-A, pages 186 to 188
d. Wire gage	NavPers 10623-A, pages 189 to 191
e. Micrometer	NavPers 10085, pages 5 to 15 NavPers 10623-A, pages 175 to 183
f. Dial test indicator	NavPers 10623-A, pages 195 to 197
g. Scribers	NavPers 10085, page 56
h. Screw pitch gage	NavPers 10623-A, pages 77 to 79

MEASURING, MARKING, AND TESTING

Measuring is the act of determining the dimensions of an object by use of measuring tools.

Marking is the making of an impression on work for visual reference.

Testing is the check of measurements.

When measuring, the right tool to be used is the one that is the handiest and easiest to work with.

When using marking devices, the points must be ______________________________

____.

When testing or checking measurements, use the gage ______________________________

____.

When measuring, marking, or testing, never use any tool that will ______________

____.

STEEL RULE

The most accurate type of rule for making measurements is the ________________

____.

It is graduated in divisions to ______________________________ inch.

Measurements should not be made from ______________________________.

You can't make accurate measurements if the rule scratched and dented, or if it's marks are worm away. When you aren't using it, keep ______________________________

____.

CALIPERS

Calipers are a type of measuring device and have no scale.

Outside calipers are used to ____

____.

Inside calipers are used to ____

____.

The "Set" of a caliper is the ____

____.

The "Set" of a caliper must be measured with a ______________________________

____.

Calipers are made in enough shapes and sizes to handle any job.

FEELER GAGE

A feeler gage or "thickness" gage is used to ______________________________

____.

A feeler gage contains blades ____

____.

Any clearance, up to the total of all the blades, may be measured by______________

____.

Before using a feeler gage, always______________________________________

____.

WIRE GAGE

A "Sheet metal" and wire gage is used to________________________________

____.

It is important to know which type of gage is used because__________________

____.

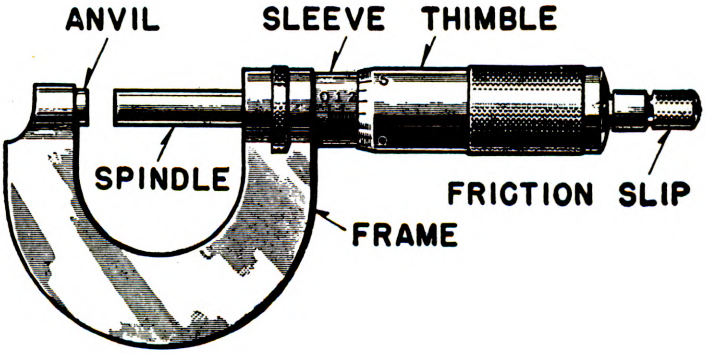
MICROMETERS

A micrometer is used for____

____.

Micrometers come in varying sizes and types depending on the measurement to be taken.

Parts of a 1-inch outside micrometer.



OUTSIDE MICROMETER--NOMENCLATURE

To read the micrometer scales:

1. Two scales

    a. Sleeve scale

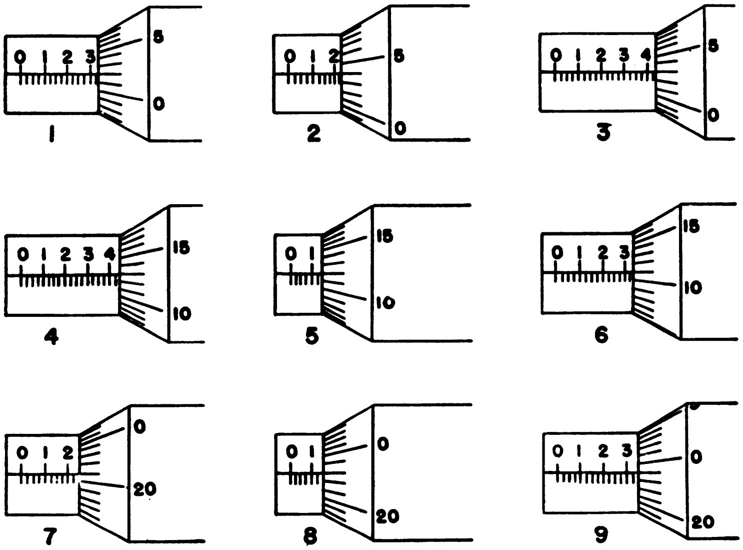
        (1) Each graduation equals________________________inch.
        (2) Each numbered graduation is________________________inch from the previous numbered graduation.

    b. Thimble scale

        (1) Each graduation equals________________________inch.
        (2) Every____________graduation is numbered.

c. One revolution of the thimble moves the spindle the distance of one space on the sleeve scale.

2. Work out the answers to the problems in the following figure.



1. ____________ inch 2. ____________ inch 3. ____________ inch

4. ____________ inch 5. ____________ inch 6. ____________ inch

7. ____________ inch 8. ____________ inch 9. ____________ inch

A Micrometer must be kept ____________________ and stowed in a ________

____________________________________.

DIAL TEST INDICATOR

A Dial Indicator is a precision tool used to ____________________________

____.

A Dial Indicator will show ____________________________________

____.

SCRIBERS

A Scriber is used to ____________________________________

____.

A plain machinist's scriber is a slender piece of tool steel, tapered to a sharp point at each end. One end may be bent at a right angle.

The point of a scriber must always be kept ____________________.

When using the scriber, make a firm, strong line the "first" time. Don't retrace.

SCREW PITCH GAGE

A Screw Pitch Gage is used to ____________________________________

____.

SECTION VIII

TOPIC 7

MISCELLANEOUS TOOLS

A. You have learned: References:

1. About fire control in general
2. About d-c and a-c circuits
3. About safety precautions
4. About electrical machinery
5. About basic electronics
6. About general purpose tools
7. About wrenches
8. About metal cutting tools
9. About metal fasteners
10. About soldering
11. About measuring tools

B. You are learning:

1. The identification, use, and care of paint brushes	NavPers 10085, pages 280 to 285
2. The identification and use of the following miscellaneous tools:	
1. Bolt cutters	NavPers 10623-A, page 16
2. Snips and nippers	NavPers 10623-A, pages 15 and 16, 35 to 38
3. Twist drill gage	NavPers 10623-A, pages 59 to 60 NavPers 10085, pages 186 to 188
4. Screw and bolt extractors	NavPers 10085, pages 213 to 215
5. Dividers and mechanical fingers	NavPers 10623-A, pages 212 and 213 NavPers 10085, pages 54 to 56, 62, 64 and 65

PAINT BRUSHES

Painting is done to preserve surfaces, and unless the surface is properly prepared, good preservation will not be possible. Apply paint only to clean, dry surfaces. A surface should be prepared by first removing all loose paint and rust, then by cleaning the surface of all dust and dirt. If rust is not removed, the rusting action will continue under the paint.

Paint brushes come in various sizes and shapes. The proper brush to use on a surface depends on the size and type of surface.

The three parts of a paint brush are:

1.______________________________

2.______________________________

3.______________________________

To properly care for a paint brush you should ______________________________

____

____

BOLT CUTTERS

1. Bolt cutters are used for ______________________________

   ____

2. The jaws are usually ______________________________ and made of

   ______________________________.

3. When using bolt cutters, avoid ______________________________.

SNIPS AND NIPPERS

1. Snips are used to ______________________________

2. The types of snips and their uses are:

   a. Straight snip

      (1) Used for ______________________________

      ____

   b. Scroll-pivoter snips

      (1) Used for ______________________________

      ____

   c. Circular snips

      (1) Used for ______________________________

      ____

   d. Hawksbill snips

      (1) Used for ______________________________

      ____

   e. Combination snips

      (1) Uses: ______________________________

      ____

   f. Special snips

      (1) Uses: ______________________________

      ____

3. Nippers are used for ____________________

____

TWIST DRILL GAGE

Twist drill gages are used to ____________________

____

SCREW AND BOLT EXTRACTORS

Screw and bolt extractors are used to ____________________

____

DIVIDERS AND MECHANICAL FINGERS

Dividers are compass-like tools used to ____________________

____

Mechanical fingers, or pickup tongs, are used to ____________________

____

SECTION IX

GUN FIRE CONTROL SYSTEM MK 51

Topic No.	Topic Title	Sheet
1.	Amplidyne Power Drive Mk 4	IX-1-1
2.	Gun Director Mk 51 Mod 2	IX-2-1
3.	Gunsight Mk 14 Mod 8	IX-3-1
4.	Sound-Powered Telephones	IX-4-1
5.	Gun Fire Control System Mk 51	IX-5-1

SECTION IX

TOPIC 1

AMPLIDYNE POWER DRIVE MK 4

A. You have learned:

1. About fire control in general
2. About basic electricity and electronics
3. About safety precautions
4. About basic hand tools

B. You are learning:

	References:
1. What Section IX contains	
2. About the power drive in general	NavPers 10171, pages 221-224. OP 821A, pages 12-48, 106-123.
3. About the magnetic controller circuits	OP 821A, pages 103-106.
4. About the amplidyne generator	NavPers 10170, pages 85-101. OP 821A, pages 69-74.
5. About the converter amplifier	NavPers 10171, pages 224-241. OP 821A, pages 54-68.
6. About the local control circuits	NavPers 10171, pages 253-255. OP 821A, pages 89-92.
7. About the synchronizing circuits	NavPers 10171, pages 245-253. OP 821A, pages 77-88.
8. About the stabilizing circuits	NavPers 10171, pages 241-245. OP 821A, pages 100-103.
9. About the limit circuits	NavPers 10171, pages 255-258. OP 821A, pages 93-100.
10. Casualty analysis of the power drive	NavPers 10171, pages 195-199. OP 821A, pages 127-253.
11. Preventive maintenance of the power drive	OP 821A, pages 127-222.

C. You will acquire skill in:

1. Making the following adjustments:
    a. Circuit balance adjustment (R19)
    b. Synchronizing velocity adjustment
    c. Limit pull-out adjustment
2. Correcting system casualties

INTRODUCTION TO SECTION IX

In this section you will learn about a complete fire control system--Gun Fire Control System Mk 51 Mod 2. This section is divided into five topics.

Topic 1 covers Amplidyne Power Drive Mk 4. In this topic you will learn how the power drive works, how to make adjustments to the drive, and how to properly maintain, and locate the casualties in, the drive.

Topic 2 covers Gun Director Mk 51 Mod 2. In this topic you will learn about the director and how to properly maintain it.

Topic 3 covers Gun Sight Mk 14 Mod 8 used with the director. Here you will learn how the gun sight works and how to maintain it. You will also learn how to operate the sight and the director.

Sound-powered telephones are taken up in Topic 4. In this topic you will learn how the sound-powered telephones operate and the types of circuits employed in their use. You will also learn how to properly care for the phone and the correct talking procedures that must be used on sound-powered telephone circuits.

Finally, in Topic 5, the various components of the system--sight, director, and mount drive--are combined, and the action of the system, as a whole, is studied. Also you will learn the routine tests and maintenance that must be performed on the system in order that it will continue operating properly.

FAMILIARIZATION WITH THE POWER DRIVE

1. What are the three methods of control? Briefly describe each method.

a.____

____

____

b.____

____

____

c.____

____

____

2. What are the major units of the train or elevation power drive? Briefly describe each unit and its location aboard ship.

a.____

____

____

b.____

____

____

c.____

____

____

d.____________________

3. What unit generates the signal for LOCAL control? Where is it located?

4. What is the function of the synchro transmission system? In what type of control is it used?

5. What is the purpose of the selector switch? Where is it located aboard ship?

6. What is the function of the stabilizing tachometer generator? Where is it located aboard ship?

7. What is the function of the limit stop assembly?

8. What is the function of the magnetic brake? When is it applied?

9. What units are located in the controller cabinet?

10. What units are located in the amplifier cabinet?

MAGNETIC CONTROLLER CIRCUITS

1. What two power supplies are controlled by the controller circuits?

2. Where is the door interlock switch located? What is its purpose?

3. When is the under voltage relay energized?

4. How are the overload relays reset?

5. What happens when the main disconnect and door interlock switches are closed?

6. What units are energized when the START button is pressed?

7. How is the mount placed in AUTO operation?

AMPLIDYNE GENERATOR

1. List the advantages of the amplidyne-type drive.

2. List the disadvantages of the amplidyne-type drive.

3. Will the amplidyne generator have a power output if the control fields are balanced? Why?

4. What type of electrical device is used to rotate the amplidyne generator?

5. Why is one set of brushes shorted together in the amplidyne generator?

CONVERTER AMPLIFIER

1. What is the function of the converter stage of the amplifier?

2. When is transformer T5 energized?

3. What is the purpose of T5?

4. What is the purpose of R8?

5. Resistors R18, R19, R20, and R36 are in the plate circuits of V3 and V4. They are used to provide signal voltage to V1 and V2 grids. Why is R19 variable?

6. What is the function of the second stage of the converter amplifier?

7. What is the purpose of transformer T7? When is T7 energized?

8. What is the function of V8?

9. How is R22 used in the amplifier circuit?

10. What is the purpose of the voltage divider network consisting of R23 and R24?

11. What is the purpose of the voltage divider network consisting of R25 and R26?

12. What is the purpose of R27 and R28? What are they called?

LOCAL CONTROL CIRCUITS

1. In LOCAL control, where does the signal to the amplifier originate?

2. How does R32 affect the LOCAL control signal? Where is R32 located?

3. How is the signal for the LOCAL signal completed to the amplifier?

4. How is the AUTO signal prevented from reaching the amplifier when in LOCAL control?

5. Describe the operation of V3 and V4 for a right train signal in LOCAL control.

SYNCHRONIZING CIRCUITS

1. What is the purpose of the synchronizing circuit?

2. How is transformer T4 used in the synchronizing circuit?

3. Besides heating the filaments of the tubes, how does the secondary of transformer T3 affect the synchronizing tubes V5 and V6?

4. What is the purpose of transformer T7, and when is it energized?

5. What is the purpose of R39?

6. What is relay P1 used for? When is it energized?

7. The synchronizing circuits for train and elevation are the same with two exceptions. What are they, and why are they different?

STABILIZING CIRCUITS

1. What is the purpose of the stabilizing circuits?

2. Where do the three stabilizing voltages originate?

3. Why are the potentiometers R9, R13, and R10 in the stabilizing circuits? Give the purpose of each.

4. Explain how R7, C1, and C2 are used in the stabilizing circuit.

LIMIT CIRCUITS

1. What is the purpose of the limit circuits?

2. Where are the limit switches located? Are they normally open or closed?

3. What is the purpose of the limit relays P2 and P3?

4. What is P5 called and what does it do in the limit circuit?

5. Explain how V7 acts as a limiting device in the limit circuit.

6. Explain the function of R27 and R28 in the limit circuit.

7. Describe the action of the limit circuits in automatic when hitting a right limit.

CASUALTY ANALYSIS

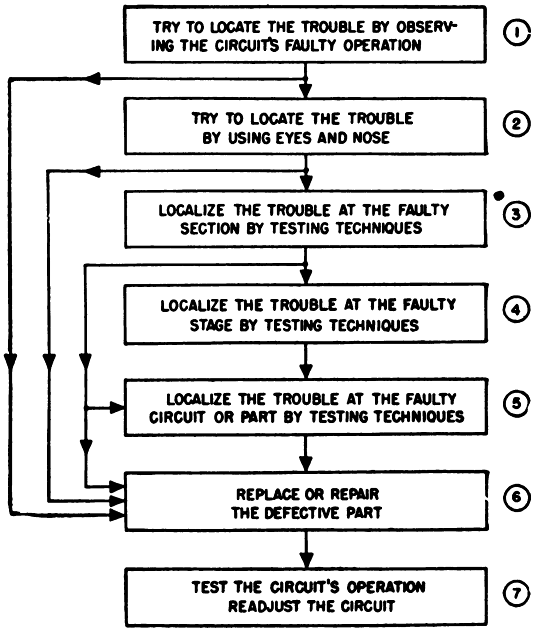
Detailed casualty analysis, or trouble-shooting, of the power drive is covered in OP 821A, Chapter 8, pages 223 through 241. There are, however, some general points about trouble-shooting that you should know and follow.

You'll spend half your time in TROUBLE-SHOOTING. Most of that time you'll be locating trouble BEFORE it happens--checking circuits and hunting out weak spots and sick parts BEFORE they cause trouble.

TROUBLE-SHOOTING is actually two jobs--LOCATING and FIXING. Once you've FOUND the trouble, you ought to have no trouble in FIXING it. But finding it takes a combination of know-how, curiosity, and instinct. Plus some accurate meters that you know how to use! Efficient trouble-shooting calls for an orderly, systematic plan of attack. No use leaping from end of the gear to the other end, guessing that ''maybe the trouble is here.'' You might be wearing your gold horseshoe that day and stumble right onto the trouble--but you're more likely to waste time and overlook the trouble spot six or eight times.

A good time-saving, trouble-shooting procedure is laid out in the following figure. The first five blocks are the steps in LOCATING trouble, and the last two blocks are the steps in REPAIRING the trouble and getting the circuit back in operation.

You will ALWAYS follow the last two steps. But many times you'll be able to skip some of the first five--you may be able to locate the trouble without going through steps 3, 4, and 5. Follow the arrows in the figure. They show you how to skip some of the locating steps.


TRY TO LOCATE THE TROUBLE BY OBSERVING THE CIRCUIT'S FAULTY OPERATION
①
TRY TO LOCATE THE TROUBLE BY USING EYES AND NOSE
②
LOCALIZE THE TROUBLE AT THE FAULTY SECTION BY TESTING TECHNIQUES
③
LOCALIZE THE TROUBLE AT THE FAULTY STAGE BY TESTING TECHNIQUES
④
LOCALIZE THE TROUBLE AT THE FAULTY CIRCUIT OR PART BY TESTING TECHNIQUES
⑤
REPLACE OR REPAIR THE DEFECTIVE PART
⑥
TEST THE CIRCUIT'S OPERATION READJUST THE CIRCUIT
⑦

Now analyze each step in the trouble-shooting procedure. This will tell you what to do as you follow the blocks in the figure.

Step 1

TRY TO LOCATE THE TROUBLE BY OBSERVING THE SYSTEM'S FAULTY OPERATION. This means applying a signal input, then locating the trouble by finding the CAUSE that produces FAULTY OPERATION.

For example, say an amplifier has two points--local and automatic. You would switch the selection and observe the operation with each input. If the drive operated perfectly in local, but faulty in automatic, you'd know the trouble was in the source of the automatic signal. On the other hand, if automatic operation was perfect, and local operation was faulty, you'd know the trouble was in the source of the local signal.

If step 1 tells you exactly where the trouble is, you can skip steps 2, 3, 4, and 5, and go directly to steps 6 and 7. But if step 1 does not locate the trouble, go on to step 2.

Step 2

INSPECT THE FAULTY CIRCUIT WITH YOUR EYES AND NOSE. This means that step 1 has localized the trouble at one part of the equipment. Step 1 tells you whether the trouble is in the automatic synchro system, or in the local control system, or in the power supply, or in the amplifier--or just where.

As an example, say that the trouble is localized at the amplifier. Then, you apply step 2 to the amplifier. LOOK for external defects before you dive into the works. LOOK for loose terminals, loose tubes, dirt, and moisture. LOOK for gassy tubes--they show up by giving off a blue glow. LOOK for any hot parts--any evidence of charring. In fact, LOOK FOR ANYTHING THAT IS NOT NORMAL.

Next, turn the chassis over, and do some more LOOKING. Burned parts, sparks, burned insulation, or loose leads are sure signs of trouble. Your eyes will do most of the work in step 2, but don't forget to use your nose. Sniff. If you smell burned insulation, follow up the sniff. It may be a shortcut to step 6.

Remember, when you're shooting-trouble, you're fighting time. Five or ten minutes is enough for step 2. If you can't locate the trouble with your eyes or nose within the time, go on to step 3.

Step 3

LOCALIZE THE TROUBLE AT THE FAULTY SECTION BY TESTING. Step 3 is used when steps 1 and 2 fail. In other words, if your eyes and your nose fail to localize the trouble, test with meters.

Most FC amplifier circuits can be divided into three sections--the signal section, the power supply, and the amplifier proper. By measuring the voltage output of each of these three sections, you'll usually localize the trouble at the faulty section.

Step 4

LOCALIZE THE TROUBLE AT THE FAULTY STAGE BY TESTING. This means tracing a signal within the section until the FAULTY STAGE is found.

There are several ways of signal tracing. But the most common method is to trace the actual signal through the section.

Step 5

LOCALIZE THE FAULTY CIRCUIT, OR PART, BY TESTING. There are three ways to localize the FAULTY CIRCUIT, OR PART--by SIGNAL TRACING, VOLTAGE TESTS, and CONTINUITY TESTS. This is called PIN-POINTING the casualty.

Pin-pointing the casualty is usually done by continuity and voltage tests. These tests are outlined in the OP's and OD's.

Step 6

REPLACE OR REPAIR THE DEFECTIVE PART. You know that ALL replacements or repairs should DUPLICATE the defective part. But in a pinch, you can use two resistors or two condensers PROPERLY CONNECTED TO DUPLICATE THE VALUE of the defective part. However, such substitutes are always TEMPORARY. The PERMANENT replacement should be made as soon as the correct parts are available. Remember--PERMANENT replacements are always EXACT duplicates.

Step 7

TEST THE CIRCUIT OPERATION--READJUST THE CIRCUIT IF NECESSARY.

After you make either temporary or permanent repairs, ALWAYS TEST THE CIRCUIT. Use the operational tests given in the OP's and OD's. These will tell you whether you have to make circuit adjustments.

GENERAL MAINTENANCE

1. Will moisture affect Amplidyne Power Drive Mk 4? What precautions should be taken against moisture?

2. Explain how the bearings of the tachometers, amplidyne generators, and d-c drive motors should be lubricated.

3. What should you look for when inspecting the brushes of the tachometers, amplidyne generators, and d-c drive motors?

4. Explain how to maintain the commutators of the tachometers, amplidyne generators, and d-c drive motors.

5. What main precaution should be observed when maintaining commutators?

6. Explain how to maintain the relays and contactors of the power drive.

7. What precaution should be observed when cleaning relays and contactors?

SWITCHES AND RELAYS

Main Disconnect Switch

Location: Five-pole switch on the right-hand side of the control unit. When the switch is closed, the door is locked shut.

Operation: It controls the three wires and phases of the 440-volt supply, and one side each of the 115-volt reference voltages for train and elevation.

1. Switch OPEN--cuts off all power to both the train and elevation power drives except the synchro circuits.
2. Switch CLOSED--the three 440-volt lines are energized as far as the line contactor (LC). The 115 volt (supply) is completed, through the door interlock, to the following points:
   - a. Blower motor of amplifier cabinet, which starts to run.
   - b. Primary of filament transformer T3 whose secondaries commence heating the tube filaments.
   - c. Thermal relay (TR).
   - d. Limit Switches. If these are closed (gun between the limits), relays P2 and P3 are energized (closed), causing the brake (BR) and limit (P5) relays to energize (close).
   - e. Correspondence meter, which should operate.
   - f. If Selector Switch is in LOCAL, the local power relay (P4) should energize (close).

Door Interlock Switch

Location: On the door of the amplifier cabinet, and is closed when the door is closed.

Operation: Switch opens when the amplifier cabinet door is opened. With the switch open, the 115-volt reference voltage for both train and elevation will be opened. Power drive will be inoperative.

Selector Switch

Location: Train switch is located in the train drive unit and is positioned by the train selector lever.
Elevation switch is located in the elevation drive unit on the left side of the mount, and is positioned by the elevation selector lever.

Operation: The train and elevation selector switches are similar in operation. With the selector in each of its positions, the following actions take place.

Selector lever in MANUAL

1. All circuits through the selector switch are OPEN.

Selector lever in LOCAL

1. Output circuit of the amplidyne generator is completed to the drive motor through contacts 1 and 2 of the selector switch.

2. Start and run circuits are completed to the master switch through contacts 3 and 5.
3. Error signal circuits from the CT's are completed to T1 and T4 through contact 4.

Master Switch (Start-stop push-button switch)

Location: The train and elevation master switches are located on their respective drive units on the mount. Their operation is identical. The START makes contact when held down, but springs back and opens the contacts when released. The STOP button breaks contact when held down, but springs back and restores contact when released. It breaks both the starting and running circuits.

Operation: The selector lever and switch must be in the LOCAL power position before the START button is depressed. The START switch controls the starting circuit. When it is depressed (makes contact) the following actions take place:

1. The POWER ON light at the master switch will light.
2. The line contactor relay (LC) will energize, which in turn causes the under voltage relay (UV) and the magnetic brake to energize.
3. If the overload relay (OL) is not closed it will now close, completing the 440-volt circuit to Amplidyne Generator.
4. The blower motor of the drive motor will start to run.
5. Primaries of T5 and T7 will receive 115 volts. When the START button is released the running circuit will keep these energized until the STOP button is depressed.

Limit Switch

Location: There are two train limit switches (right and left) located in the train drive unit. The two elevation limit switches (upper and lower) are located in the elevation drive unit. The limit switches are actuated by the limit cams.

Operation: The operation of all four limit switches is similar, the only difference being the limit pull-out circuit that becomes energized when a switch is opened. For example, if the right train limit switch is opened when the mount is in either LOCAL or AUTO operation, the following actions will take place:

1. The right limit relay (P2) will open, causing
2. the limit relay (P5) to open, and
3. the brake relay (BR) to open, which in turn will cause
4. the magnetic brake to deenergize and apply the brake to the drive motor shaft.

If the left train limit switch had been opened instead, the only difference would have been that the left limit relay (P3) instead of P2 would open.

Line Contactor Relay (LC)

Location: There are two line contactor relays. One for train (TLC) and one for elevation (ELC). Both relays are in the controller cabinet.

Operation: The relay has four sets of contacts all of which are open when the relay is deenergized.
The following conditions must exist in order to energize the relay:

1. Main disconnect switch--Closed.
2. Fuses--good.
3. Door interlock--closed.
4. Selector switch--LOCAL.

   a. Note: Once the relay is energized, the selector switch may be shifted to AUTO if desired, and the relay will stay energized.

5. Master switch--START button depressed.

   a. Note: Once the relay is energized, the START button may be released, and the relay will remain energized.

When the line contactor is energized, the following circuits are completed:

1. Energize under voltage relay (UV).
2. 440 volts, 3-phase, to the motor of the Amplidyne Generator, if the overload relay (OL) is closed.
3. 440 volts, to the magnetic brake, if the brake relay (BR) is closed.

The line contactor will be deenergized (open) whenever the 115-volt circuit to it is open for any reason.

Overload Relay (OL)

Location: There are two overload relays, one for train (TOL), and one for elevation (EOL). They are both located in the controller cabinet.

Operation: Current supplying the generator power motor passes through this relay. Should the current become excessive due to an overload on the motor, the relay will open after a time delay which is dependent upon the overload. Once it opens, it remains open until reset by the resetting coil. When reset, it stays closed until another overload occurs. The resetting coil is energized when the START push button is held down. The contacts of this relay close the running circuit which keeps the line contactor energized after the START push button is released.

Under Voltage Relay (UV)

Location: There are two under voltage relays. One for train (TUV), and one for elevation (EUV). They are both located in the controller cabinet.

Operation: The UV relay has three sets of contacts. Two are open, and one is closed when the relay is deenergized. This relay is energized by one phase of the 440-volt circuit controlled by the line contactor. When voltage in this line becomes dangerously low or fails completely, the relay opens. One contactor of this relay closes the running circuit and is in series with the overload relay. One contactor connects the reference voltage with transformers T1 and T5. When deenergized, one contact places a short across the drive motor to bring it to a quick stop.

Thermal Relay (TR)

Location: There are two thermal relays. The train relay is in the train drive motor, and the elevation relay is in the elevation drive motor.

Operation: The TR relay is operated by the temperature of the drive motor. If the motor is overheated for any reason, the relay closes. This completes the circuit to the motor overload light which warns the operator of trouble. The mount does not stop automatically, as with the UV and OL relays, but should be stopped by pressing the STOP button. When the motor cools off, the relay opens, and the warning light goes out.

Brake Relay (BR)

Location: There are two brake relays. One for train (TBR), and one for elevation (EBR). They are both in the controller cabinet.

Operation: The BR relay has two sets of contacts which are normally open when the relay is deenergized. To energize the relay, both the right and left limit relays (P2 and P3) must be energized. When the BR relay is energized the contactors complete the 440-volt circuit to the magnetic brake.

Magnetic Brake

Location: There are two magnetic brakes. One is the train drive unit on the drive motor shaft, and the other in the elevation drive unit.

Operation: The magnetic brake is primarily intended to prevent any movement of the mount when the gun is not in use. In MANUAL control the brake is released mechanically when the selector lever is placed in position; in AUTO and LOCAL power it is operated electrically. When current flows through the brake coil, the brake shoes are held from the drive shaft. When the current is cut off, a spring clamps the brake shoes to the shaft, and thus halts the mount. The brake is on when the current is off; therefore, it helps to bring the mount to a stop when the power fails, or is cut off.

1. Main disconnect switch--closed
2. Brake relay (BR)--energized
3. Line contactor (LC)--energized

Synchronizing Relay (P1)

Location: There are two synchronizing relays (P1), one each in the train and elevation amplifiers of the amplifier unit. The operation of both relays is the same.

Operation: The relay (P1) is normally deenergized, and its two sets of contacts are open. In order to energize the relay, either tube V5 or V6 must be conducting. When energized, the contacts on the relay

1. Short the fine error signal from the 36X CT.
2. Complete the coarse error signal circuit to the first stage of the converter amplifier.

In order for either tube V5 or V6 to conduct, the drive must be operating in AUTO power and either

1. The "coarse" error signal voltage is such a size as to equal a synchronization error of 2 degrees or greater, or
2. The mount is in one of the limits.

Right Limit Relay (Train), Upper Limit Relay (Elevation) (P2)

Location: These two relays are located on their respective amplifiers in the amplifier cabinet. The operation of both relays is identical.

Operation: The P2 relay is normally energized when the mount is operating in either LOCAL or AUTO power and the right (upper for elevation) limit switch is closed. When the relay is energized, two sets of contacts are open while the third is closed. When the right limit switch is opened, relay P2 becomes deenergized, causing the following:

1. One set of contacts ''open'' which will
   a. Deenergize the brake-relay (BR), causing the brake to be applied to the shaft of the drive motor.
   b. Deenergize relay P5.
2. Another set of contacts ''close'', completing a circuit that prevents a right train signal from reaching the converter amplifier.
3. The third set of contacts ''close'', completing the ''right limit pull-out circuit.'' This circuit is used only in AUTO and allows a very small left signal from the coarse CT to reach the converter amplifier. This prevents the mount from surging when coming out of the limit in AUTO.

Left Limit Relay (Train), Lower Limit Relay (Elevation) (P3)

Location: These two relays are located on their respective amplifiers in the Amplifier Cabinet. They are identical in operation.

Operation: Relay P3, like P2, is normally energized when the mount is operating in LOCAL or AUTO within the limits. When the left (lower for elevation) limit switch is opened, relay P3 becomes deenergized causing the following:

1. One set of contacts ''open'' which will
   a. Deenergize the brake relay (BR)
   b. Deenergize relay P5
2. Another set of contacts ''close'', completing a circuit that prevent a left train (decrease elevation) signal from reaching the converter amplifier.
3. The third set of contacts ''close'', completing the ''left (lower) limit pull-out circuit. This circuit is used only in AUTO and allows a very small right (increase) signal from the coarse CT to reach the converter amplifier.

Limit Relay (P5)

Location: There are two limit relays (P5's), one each on the train and elevation amplifiers in the amplifier cabinet.

Operation: The operation of both relays is identical. Relay P5 is normally energized with the mount operating within the limits in either LOCAL or AUTO power. When either limit is reached the relay P5 will be deenergized, causing both sets of contacts to close. One set of contacts shorts the signal from the fine CT. The other set of contacts completes a circuit which applies a signal to the converter amplifier, from the stabilizing tachometer, in opposition to the mount movement. This signal aids in bringing the mount to a fast stop when the limits are reached.

Local Power Relay (L4)

Location: There is one local power relay (P40 for train and one for elevation). They are located on their respective amplifiers in the amplifier cabinet.

Operation: Relay P4 is energized when the selector switch is in LOCAL, and the main disconnect switch is closed. When the relay is energized, the following action takes place.

1. Two sets of contacts "close," completing the circuit from the local power tachometer to the converter amplifier. This applies the LOCAL signal to the amplifier.
2. The third set of contacts "open." This prevents the synchronizing circuit from operating since these contacts are in the plate circuits of V5 and V6.

ADJUSTMENT PROCEDURES

Circuit Balance Adjustment (R19)

The object of this adjustment is to insure that the outputs of V1 and V2 in the amplifier will be equal when there is no signal input. This prevents the mount from creeping when in LOCAL power. This also balances the amplifier output when the drive is operated in AUTO. Before making this adjustment you should make sure that there are no casualties in the power drive. Correct any casualties before making this adjustment.

Procedure for adjusting R19

1. At the controller cabinet, open the main disconnect switch.

2. Open the doors on both the controller and amplifier cabinets.

3. Disconnect the amplidyne drive motor in the controller cabinet.

   a. For train--Remove leads GMP 121, GMP 122, and GMP 123 from terminals 34, 35, and 36 of the terminal strip at the bottom of the controller cabinet.
   b. For elevation--Remove leads GMP 131, GMP 132, and GMP 133 from terminals 1, 2, and 3 of the terminal strip at the bottom of the controller cabinet.
   c. CAUTION: When these leads are removed, make sure that they are clear and do not touch or make contact with each other, or any other lead, or the cabinet. Do not attempt to remove these leads with the main disconnect switch closed. These leads carry 440 volts when energized.

4. Complete the circuits through the door interlock switch. This can best be done by clamping the switch closed.

5. Connect milliameters in the amplidyne field circuit, observing the proper polarity.

   a. Use two 100-ma d-c milliameters.
   b. For train--At terminal strip "A" on the train amplifier, remove the leads to terminals 3 and 5. Connect these leads to the positive (+) terminals of the two milliameters. Connect the negative (-) terminals of the milliameters to terminals 3 and 5, respectively, on terminal strip "A." This places one meter in series with the plate circuit of V_1 and the other meter in series with the plate circuit of V_2.
   c. For elevation--Same connections as for train except make all connections to elevation amplifier.

6. Recheck all connections.

7. Energize equipment.

   a. At the controller cabinet, close the main disconnect switch.
   b. At the mount, place the selector lever in LOCAL.
   c. At the mount, depress the START button. Release the button after the POWER-ON light is burning.

8. At the amplifier, adjust R19 until both milliameters show the same value (approximately 30 to 40 ma).

9. Deenergize the equipment.

   a. At the controller cabinet, open the main disconnect switch.

10. Disconnect the milliameters and reconnect the leads to their respective terminals.

11. Reconnect the leads to the amplidyne drive motor at the controller cabinet.

12. Check to see that all connections are properly made.

13. Remove the clamp from the door interlock.

14. Close and secure the doors to both the amplifier and controller cabinets.

15. Energize the equipment.

   a. Close the main disconnect switch.
   b. Place the selector lever in LOCAL.
   c. Depress the START button.

16. Observe that the mount does not "creep." If the mount does creep, the adjustment was improperly made. Readjust.

NOTE: In an emergency the following approximate adjustment for R19 can be followed:

a. Energize the equipment in LOCAL power.
b. Observe the angle-checking dials for mount creep.
c. Adjust R19 until creep is eliminated.
d. Secure equipment.

Synchronizing Velocity Adjustment (R39)

This adjustment affects the automatic power operation of the power drive. If the mount is out of correspondence with the signal from the director, it should synchronize at a certain rate. This should be approximately 33 degrees per second in train and 27 degrees per second in elevation. The speed may be adjusted by the synchronizing speed potentiometer R39 on the amplifier chassis. This adjustment is not critical and no change should be made unless the synchronizing speed differs widely from the figures given.

Procedure for checking the synchronizing speed

1. Lock the director at zero degrees in train and elevation.

2. Energize the train power drive in LOCAL.

3. By means of the train correspondence indicator, bring the mount and director into exact correspondence.

4. Read the angle-checking dials.

5. In LOCAL, move the mount 165 degrees out of correspondence in train.

6. Shift the train selector lever to AUTO. At the same time start a stopwatch.

7. When the correspondence indicator reads ZERO, stop the stopwatch. The drive is synchronized.

8. The mount should synchronize in 5 seconds in train.

   a. If the mount synchronizes in less than 5 seconds, it indicates that the synchronization speed is too fast. Adjust R39, on the train amplifier, by turning the adjustment to the left (CCW) to decrease the speed.

   b. If the mount takes more than 5 seconds to synchronize, it indicates that the synchronization speed is too slow. Adjust R39, on the train amplifier, by turning the adjustment to the right (CW) to increase the speed.
   c. If R39 is adjusted, the synchronizing speed check should be rerun.

9. Deenergize the train power drive.

10. Energize the elevation power drive.

11. By means of the elevation correspondence indicator, bring the mount and director into exact correspondence.

12. Read the angle-checking dials. (Should read approximately 2,000 min.)

13. In LOCAL, elevate until the mount is out of correspondence by 4860 minutes. (The dials should read approximately 6860 min.)

14. Shift the elevation selector lever to AUTO. At the same time start a stopwatch.

15. When the correspondence indicator reads ZERO, stop the stopwatch.

16. The mount should synchronize in three (3) seconds in elevation.

    a. If necessary, adjust R39 on the elevation amplifier.

17. Deenergize the elevation power drive.

Limit Pull-out Adjustment (R37, R38)

Read, and carefully follow, the procedure given in OP 821-A, pages 189 and 190.

Stabilizing Adjustments (R10, R13, and R9)

These adjustment should not be attempted unless absolutely necessary, due to replacement of one or more of these potentiometers, or due to the installation of a spare amplifier. DO NOT attempt these adjustments unless you have the proper meters as specified in OP 821-A.

Read, "Stabilizing Adjustment" in OP 821-A, page 191.

Read and, if necessary, follow the procedure given under "Spare Amplifier---Installation" in OP 821-A, pages 217, 218, and 219.

Setting The Limit Cams

The procedure for setting the limit cams is given in OP 821-A, pages 177 and 178.

Adjustment of the Magnetic Brake

The procedure for adjusting the magnetic brake is given in OP 821-A, pages 191 and 192.

Overload-Relay Adjustment

The procedure for adjusting the overload relay is given in OP 821-A, pages 216 and 217.

SECTION IX

TOPIC 2

GUN DIRECTOR MK 51 MOD 2

A. You have learned:	References
1. About fire control in general	
2. About basic electricity and electronics	
3. About safety precautions	
4. About basic hand tools	
5. About Amplidyne Power Drive Mk 4	
B. You are learning:	
1. The function of Gun Director Mk 51 Mod 2	
2. Construction of Gun Director Mk 51 Mod 2	OD 4424, pages 5 to 7 NavPers 16116-B, pages 623 to 624
3. Function and purpose of each major part of the director	OD 4424, pages 25 to 31
4. Maintenance of the director	OD 4424, pages 9 to 14; 19 to 24

C. You will acquire skill in:

1. Checking the synchro transmission system from director to power drive
2. Checking the firing circuit
3. Checking for proper action of the director dampers

FUNCTION OF GUN DIRECTOR MK 51 MOD 2

A. Function of the director is ____

____

____

____

____

CONSTRUCTION OF GUN DIRECTOR MK 51 MOD 2

1. Location of the director on board ship:

a. ____

b. Reason for location:

(1). ______________________________

(2). ______________________________

2. Two parts of the director:

1. ______________________________

a. Support the head
b. Contains:

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

2. ______________________________

a. Used to support and control the movement of a Gun Sight Mk 14
b. Contains or supports:

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

(5) ______________________________

(6) ______________________________

(7) ______________________________

3. Synchro Transmission System

1. Used to connect the gun and director.
2. Four synchro generators in director.

a. Purpose:

(1) Two train synchros will ______________________________

____

(2) Two elevation synchros will ______________________________

____

4. Complete Director Mk 51 Mod 2 equipment consists of:

    1. ______________________________
    2. ______________________________
    3. ______________________________
    4. ______________________________
    5. ______________________________
    6. ______________________________

FUNCTION AND PURPOSE OF MAJOR PARTS OF DIRECTOR

1. Director Pedestal

    1. Train stops ______________________________

        ____

        ____

    2. Two train synchros

        a. ______________________________

        b. ______________________________

        c. ______________________________

    3. Train damper

        a. Purpose: ______________________________

        b. Description: ______________________________

        ____

2. Director Head

    1. Description: ______________________________

        ____

        ____

    2. Elevation damper

        a. Purpose: ______________________________

        b. Description: ______________________________

        ____

        ____

3. Two elevation synchros
   a. Location: ____________________
   b. Purpose: ____________________
4. Ring sight
   a. Purpose: ____________________
5. Firing key
   a. Location: ____________________
   b. Purpose: ____________________
6. Train and elevation locks
   a. Train lock: ____________________
   b. Elevation lock: ____________________

MAINTENANCE

1. Lubrication: ____________________
2. Protection from moisture:
   1. Canvas cover: ____________________
   2. Access Covers: ____________________
3. Synchro alignment: ____________________

4. Director wiring: ______________________________

____

5. Routine checks: ______________________________

____

____

6. Miscellaneous: ______________________________

____

____

SECTION IX

TOPIC 3

GUN SIGHT MK 14 MOD 8

A. You have learned:	References:
1. About fire control in general	
2. About basic electricity and electronics	
3. About safety precautions	
4. About basic hand tools	
5. About Amplidyne Power Drive Mk 4	
6. About Gun Director Mk 51	
B. You are learning:	
1. What Gun Sight Mk 14 is	Gun Sight Mk 14, OP 1040, pages 21 to 26. Gun Sight Mk 14, OD 4429, pages 5 to 7
2. Basic Principles of Gun Sight Mk 14	Gun Sight Mk 14, OP 1040, pages 11 to 21; 37 to 33
3. About the mechanics within Gun Sight Mk 14 Mod 8	Gun Sight Mk 14, OP 1040, pages 47 to 59. Gun Sight Mk 14, OD 4429, pages 43 to 49.
4. About the power unit	Gun Sight Mk 14, OP 1040, pages 60 to 66. Gun Sight Mk 14, OD 4429, page 48.
5. About the operation of the Gun Sight with Gun Director Mk 51	Gun Sight Mk 14, OP 1040, pages 41 to 46. Gun Sight Mk 14, OD 4429, pages 17 to 20. Gun Director Mk 51, OD 4424, pages 15 to 18.
6. About the maintenance of Gun Sight Mk 14	Gun Sight Mk 14, OP 1040, pages 83 to 110. Gun Sight Mk 14, OD 4429, pages 9 to 15; 20A to 37.

C. You will acquire skill in:

1. Operating Gun Sight Mk 14 with Gun Director Mk 51
2. Performing Maintenance on Gun Sight Mk 14 Mod 8

GENERAL DESCRIPTION

1. Gun Sight Mk 14 is designed to permit rapid solution of the ____________________

____

2. Provided that the operator tracks a target accurately and smoothly, the action of the gun sight is not affected appreciably by ______________________________ .

3. In the gun sight, the LOS is indicated by an ______________________________ .

4. A lead angle is generated between the LOS and LOF when the sight operator swings the director to keep ______________________________ .

5. Lead angle compensates for target movement during the ______________________________ .

6. Two mirrors are used to superimpose the ______________________________ of the field view.

7. Position of the two mirrors is controlled by the two ______________________________ through a lever system.

8. Movement of the mirrors displaces the LOS in ______________________________ to produce the required lead angle.

BASIC PRINCIPLES OF THE LEAD-COMPUTING SIGHT

1. Superelevation is the angle that is necessary to elevate the gun to correct for ______________________________ .

2. A gyro is a revolving wheel that will tend to keep spinning in the same ______________________________ .

3. When a force is applied to a gyro to move it out of its plane, the gyro is caused to ______________________________ .

4. The rate-of-turn gyro will precess until the pull of the cross-arm is exactly ______________________________ by the tension of the restraining springs.

5. The rate-of-turn gyro will remain in the pressed position as long as you continue to rotate the case at the same ______________________________ .

6. The gyro system positions a pair of mirrors so that the line of sight ______________________________ the line of fire in elevation and traverse.

7. The mirrors and lever systems ______________________________ the lead angle measured by the rate-of-turn gyros.

DETAILED DESCRIPTION

1. The four main parts of Gun Sight Mk 14 Mod 8 are:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

2. The optical system is composed of

a. ______________________ e. ______________________

b. ______________________ f. ______________________

c. ______________________ g. ______________________

d. ______________________ h. ______________________

3. Tilting the ________________ mirror causes the reticle image to move from side to side, whereas tilting of the ________________ mirror causes the reticle image to move up and down.

4. The gyro system is composed of the ______________________________ and ________________ gyro units.

5. The time lag caused by the damping discs introduces no error as long as the tracking rate is ______________________ or is oscillating about a ______________ value.

6. Spots in deflection and elevation are introduced by offsetting the ______________ ______________ by means of cams positioned by spot knobs.

7. Superelevation correction is made by the application of a __________________ ________________ at the end of a lever arm on the __________________________ of each gyro.

8. Tension of the cantilever restraining springs is adjusted by ________________ ____.

9. The temperature control system is used to ____________________________ ____.

POWER UNIT

1. The purpose of the air power unit is to supply clean, dry, compressed air for driving the ____.

2. The air dryer and intake breather of the air power unit are filled with an indicator

type of ____.

GUN SIGHT AND DIRECTOR OPERATION

When Gun Sight Mk 14 is secured, the gyro damping fluid is cold and a 30-minute warmup period is required to bring the fluid to its proper temperature (140° F.) so that the sight can be operated accurately. When on standby, it is essential that the gun sight be capable of operating with full accuracy within a few minutes. To permit this, standby condition may be one of the following:

1. Gun sights without standby wiring must have all electrical connections made and energized, and air hoses connected. The air power unit must be in operation; the gyros must be operating, and gyro unit and air heaters energized. In this condition, the sight is continuously ready for instant operation.
2. Where standby wiring is provided, the air power unit is stamped STANDBY. In this case, all electrical and air connections are made but only the ship's service supply cable to the power unit is energized, and the power unit switch is turned OFF. The standby wiring within the power unit permits the gyro unit heaters to be energized, keeping the damping fluid at the proper temperature. Before the sight can be used with full accuracy in this condition, it is necessary to turn the power unit switch to ON and then allow 3 minutes for the gyros to come up to speed.

Note: The connection box from which the ship's service supply connection is led may be fitted with a switch. If so, this switch must be ON, either to operate the gun sight or to energize standby wiring.

CAUTION: While on standby, the gun director should be left secured in its normal position, in train and at 0' elevation, with range set at its minimum figure.

PREPARING FOR ACTION

If the sight has been disconnected for securing, the first step in preparing it for action is to connect the 115-volt ship's service supply to the power unit. The junction box from which the current is led may be provided with a switch. If so, it must be turned to the ON position.

The gyro rotors will reach proper speed 3 minutes after the cut-out switch has been turned on, but the damping fluid will not reach proper temperatures until the heating units have been in operation for 30 minutes.

In an emergency, it is possible to use the sight 10 minutes after the heaters have been in operation, but it will not give accurate solutions until the full warmup period of 30 minutes has passed.

In the above, it is assumed that the system has not been left in STANDBY condition. If the system is equipped with standby wiring and the power cable has been left connected, the sight may be used with maximum accuracy 3 minutes after the cut-out switch is turned on, this 3 minutes being required for the gyro rotors to reach operating speed.

POWER UNIT PRESSURE

The power unit pressure gage should be inspected to see that the needle points to the green sector of the dial. If it does not, the sight must be checked by a qualified maintenance man.

RETICLE LAMP

Operation of both filaments of the reticle lamp should be checked by turning the reticle dimmer knob to bright position (BR) for each filament and observing reticle brightness in the sight.

NEUTRAL DENSITY FILTER

Movement of the neutral density polarizing should be checked by operating the filter lever.

RETICLE MOVEMENT

After the gyro unit has been allowed to warm up for at least 30 minutes, movement of the reticle should be checked. This is done by swinging the gun rapidly in one direction in train, bringing the reticle to its limit of travel. Then the movement of the gun is stopped and the reticle is observed as it returns to its neutral position. Its movement should be smooth and steady. This test is made in both directions, in train and in elevation. If the reticle appears to move jerkily or irregularly in returning to its neutral position, the sight is faulty and should be replaced. The faulty sight must be returned to a qualified repair station for adjustment.

CYCLING

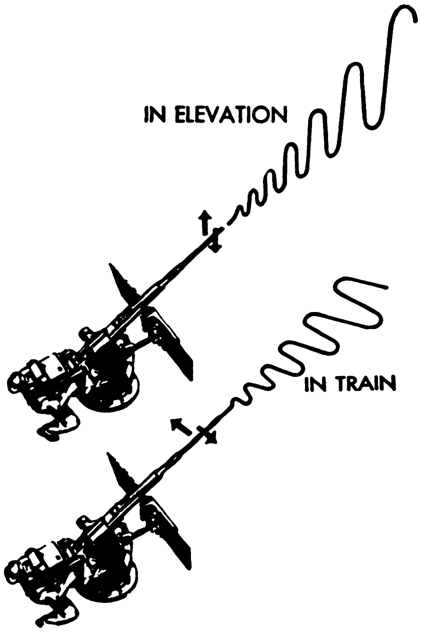
Cycling is the final step taken before placing the sight in operation. Its purpose is to settle the reticle on its true zero position in both directions and to check it for smoothness. Cycling in train can be accomplished immediately after checking reticle movement in elevation.

Cycling is accomplished in the following manner:

1. Set the range knob at maximum range. Holding the mount in a horizontal position, swing it rapidly from side to side in train.

2. Continue swinging the mount, but reduce the speed of swing so that the reticle moves through successively smaller arcs, finally coming to rest. This will be its zero position in traverse.

3. Holding the mount steady in train, repeat the above procedure in elevation, allowing the reticle to settle finally to its true zero position in elevation.



CYCLING

RETICLE BRIGHTNESS

Before actually tracking a target with the sight, it is desirable to adjust the reticle brightness so that when on the target, any further change to be made will be slight. This is done by adjusting the brightest portion of the sky, but not so intense that it will detract from vision. Reticle brightness should be adjusted only if the sight is to be used immediately; otherwise the reticle lamp is left OFF. If necessary to reduce the brightness of the background, the light filter may be shifted into position.

If the reticle is too bright, it will tend to obscure the target, and poor tracking will result. If the reticle is too dim, relative to the tracking background, the reticle will be obscured, also resulting in poor tracking.

ACTION

The preceding paragraphs describe normal procedures for putting the equipment into operation or getting ready for action. The following paragraphs describe the typical procedures for handling the equipment during action, but should be considered as illustrating function and not as advancing specific doctrines of operation.

SLEWING

When the pointer first sees the target, he turns the director rapidly in the target's direction. This rapid swing, called slewing, creates a false lead angle, since the rate of swing usually is much greater than it will be after the pointer has begun tracking the target.

Means of correcting, or holding this false lead angle to a minimum, are as follows:

1. The pointer can swing the director past the target, then bring it back on the target by turning or slewing the director in the opposite direction. If the reverse swing is made at the same rate as the original swing, the effect will be to collapse the false lead angle.
2. While the pointer is slewing, in his attempt to pick up the target, the range knob should be set at its minimum range (400 yards), thus restricting movement of the reticle. The range-setter does not set the range until the pointer is on the target.
3. NAVORD OD 2298 provides means for equipping Gun Sight Mk 14 with "caging" device so that the gyros can be held without movement until the pointer is on the target. Caging the gyro nullifies the effect of slewing on the lead angle.

The above paragraphs pertain to the movement of the director required to bring the sight on the target. Even after accurate tracking has begun and with the gyros uncaged, several seconds must elapse before the gyro units can pick up the exact angular velocity and deliver the correct lead angle.

The time for the system to adjust to any change in range setting must also be considered.

Immediately upon picking up the target, reticle brightness should be adjusted so that it is perfectly clear but not too bright to obscure the target.

As the target is picked up, the rangesetter must shift the range knob from its 400-yard setting to this estimated range.

TRACKING

Smooth accurate tracking is the most important factor in obtaining hits when using Gun Sight Mk 14. The correct lead angle depends upon the angular velocity of the target as seen from the gun sight. If the angular rate of motion of the gun is not the same as that of the target, an incorrect lead angle is generated by the sight. Additionally, if tracking is done in a jerky manner, constantly changing lead angles will be generated, none of which will be correct.

The following should be remembered by the gunner or director operator while he is tracking:

1. Keep the reticle dimmed so that it will not obscure the target, but can be seen comfortably.
2. If the background behind the target is very brilliant, use the light filter.
3. Concentrate on seeing the target, not on watching the reticle. It is impossible to keep the head in a fixed position behind the sight. Move the head whenever necessary to keep the reticle in view.

RANGE SETTING

Smooth rangesetting is another factor which will aid the pointer immeasurably in tracking.

Any abrupt change in rangesetting will make a sudden change in reticle position. This may easily throw the pointer off in tracking. Therefore, any change in range during tracking or firing must be made with a smooth motion of the range knob.

In general, there are two methods of applying range settings to the sight. In one, the range is purposely set short; in effect, the target flies into the tracer path. After the target has passed through, the range is changed by a previously established amount, and again the target approaches and flies through the tracer path.

In the other method, rather than underset or overset, the rangesetter attempts to obtain the exact range of target in its present position (by visual estimation, tracer observation, of other means), and sets and adjusts the range control accordingly.

The rangesetter must be thoroughly familiar with the action of the gun sight as well as with fire control problems.

INCOMING TARGET

If the tracers pass ahead of an approaching target, the lead angle is too great. Assuming accurate tracking, too great a range is set on the sight. If the tracers pass below or behind the target, the lead angle is too small, and the range setting too low. The first condition requires a definite change in range setting (400 or 800 yards) to bring the tracer stream to the target. If the tracer stream passes behind, the approaching target will fly into the range. This may require an increase in range, depending on the amount of the error.

The range should be reduced each time the tracer stream appears to pass ahead of the target. Decreasing the range too soon causes fire to fall continuously below and behind the target. Conversely, if the range is too great, the fire will fall ahead or above the target, and will not hit an incoming target. (Accurate tracking is assumed in all cases.)

OUTGOING TARGET

With an outgoing target the range is continuously increasing instead of decreasing. In this case, if the range is too great the tracers will still pass ahead of the target, but the target will fly into the correct range. If the tracer stream passes behind and below the target, the range is too short and must be increased to catch up with the target. In this case, the range should be increased when the tracer stream appears to fall behind the target.

Dispersion of fire, tracking error, and target size all enter into the possibility of making hits. For this reason, the gun may score hits at the range set on the target.

SPOTTING

If the range is properly set on the sight, and if tracking is accomplished smoothly and accurately, the correct lead angle will be generated, and spots will not be necessary. A number of minor errors enter into the flight of the projectile. These include drift of the projectile, wind velocity (which tends to drive the projectile from its normal trajectory), errors in bore-sighting the gun, and errors in the roller path plane of the gun. The normal dispersion of fire of the automatic weapons controlled by the gun sight should be larger than the total of all these errors. Therefore, spotting to correct such errors is unnecessary, and can be harmful.

The rangesetter should avoid applying spots while the gunner is firing. Applying spots causes sudden movement of the reticle and may throw the gunner off the target. For the same reason, range must be changed smoothly. Spots should seldom be applied and then only to correct for a known consistent error.

SECURING

The gun sight should be secured in the following manner:

1. Shift range knob to minimum range (400 yards).

2. Bring gun mount or director to secured position in train, and lock.

3. Bring gun mount to 5' elevation, and insert locking pin. (Gun director is locked at 0'.) Release elevation locking pin from its top, and move gun slowly at low elevation until pin slides into place.

4. If standby wiring is not provided, and gun is not to be left in a "ready" condition, turn power unit cut-off switch OFF.

5. Disconnect 115-volt ship's service power supply only if so ordered.

CAUTION: It is important to secure the sight in an approximately horizontal position, to allow the damping fluid in the gyros to settle in the proper position. The action of the gyros would be faulty and incorrect lead angles would be generated if the fluid were to settle incorrectly.

If the sight is inadvertently left in a highly elevated position, the following should be done before placing it in service:

1. Bring sight to a horizontal position and allow it to warm up for from two to three hours.

2. Then check the performance of the sight by making the following performance tests: dead zero test, range shift test, characteristic time test, and deflection (sensitivity) test.

When these tests show the sight to be operating satisfactorily, it is ready for service. (These tests are described in the OP on other gear.)

NOTE AND SAFETY PRECAUTIONS

The following safety precautions and notes relating to operation of Gun Sight Mk 14 are listed here for reference:

1. If standby wiring is provided and is in use, allow 3 minutes for gyros to reach proper speed.

2. Whenever the sight is not actually in use, it must be kept in an approximately horizontal position (0' for director, 5' for 20-mm mount).

3. If air pressure from the power unit is not correct, or if reticle movement is uneven, use the sight only in an emergency. Have the sight checked by a maintenance man at the earliest opportunity.

4. Always cycle the sight in train and elevation before placing it in use.

5. When slewing, always set the range knob at its minimum setting (unless gyros are caged).

6. When slewing at a high rate, it is recommended that target be picked up by "overshooting" (unless gyros are "caged").

7. If a caging device is installed, always cage the gyros when slewing.

8. Always make changes in the rangesetting with a smooth motion of the range knob.

9. Never reduce range on an incoming target until the tracer stream appears to pass ahead of the target.

10. Never increase range on an outgoing target until the tracer stream appears to fall behind the target.

11. Apply spots only when necessary. If undecided, do not spot.

12. When firing has ceased and gunner is searching for another target, immediately set range at minimum (400 yards).

13. Always secure gun mount at 5' elevation (gun director at 0') with range set at 400 yards.

14. If gun has inadvertently been secured vertically, have performance tests made before placing sight back into operation.

15. If standby is NOT provided and sight is to be used again within 30 minutes, leave power unit cut-out switch ON. If standby wiring is provided, cut-out switch can be turned OFF.

MAINTENANCE

Normal shipboard maintenance of Gun Sight Mk 14 must include certain tests made perodically to establish satisfactory operation. The following performance tests should be made, in order named, every two weeks or after 200 hours of operation:

1. Dead Zero Test
2. Range Shift and Superelevation Test
3. Deflection (Sensitivity) Test
4. Characteristic Time Test

Immediately following these tests, the gun sight should be boresighted to its mount. To insure continued alignment, boresighting may be required more frequently than indicated above.

All tests should be made as soon as practicable, after extensive firing or abnormal weather conditions, whether or not the regular test period has been reached.

PRECAUTIONS WHILE TESTING

To insure valid results, the following precautions should be taken prior to and during the performance tests:

1. A warmup period of at least half an hour must be allowed prior to beginning any test.

2. Before each performance test, the gun sight must be cycled to settle the reticle in its true zero position. If the Field Test Scale is in place while cycling, its adjustment should be checked before proceeding with the next performance test.

3. During the tests, it is essential that all motions originating outside the director and gun sight be kept at a minimum. For this reason, performance tests should be accomplished while the ship is in extremely calm water, preferably while at anchor or tied to a pier. To minimize any possible motion of the ship, tests should be made with the director trained as nearly fore-and-aft as possible.

NOTE: Performance tests made while the ship is underway will be only rough checks, and cannot be depended upon for any accurate determination of the efficiency of the gun sight.

4. In making performance tests, hold the sight motionless whenever the reticle is to be allowed to settle after a prescribed swing.

CAUTION: Whenever instructions call for rapid swinging of the gun sight, care should be taken to swing the sight only rapidly enough to bring the reticle to the end of the Field Test Scale. Repeated rapid swinging into the stops may damage a gyro unit.

TESTING EQUIPMENT

Performance tests are made using the Field Test Scale supported in the Calibration and Training Fixture Mk 1 Mod 0. Instructions for mounting and adjusting these are contained in OP 1040, pages 83 and 84.

DEAD ZERO TEST

The Dead Zero Test is performed to determine the width and height of the dead zero area, and to adjust the reticle neutral position to the center of that area. The dead zero area is that area within which the reticle may settle when returning to neutral from any lead angle.

Before beginning the dead zero test, set the gun sight in horizontal position, and adjust the range knob to maximum range. Proceed with the test as follows:

1. Swing the gun sight in train to the left so as to generate the maximum lead angle on the right side of the field test scale. Bring the sight to rest, and allow two minutes for the reticle to settle, being careful to keep the sight motionless. Using deflection spot knob, move the reticle to scale zero.

2. Swing the sight to the right, generating a maximum lead angle on the left side of the scale. Stop the movement and let the reticle settle for two minutes. Record the horizontal-displacement reading on the scale directly under the reticle center spot. This reading is the width of the dead zero area.

3. Using the deflection spot knob, return the reticle to the center of the area just determined. For example, if the reticle settled four mils to the left of scale zero, spot the reticle so that it is two mils to the left of scale zero.

4. Lock the director in train to make the dead zero test in elevation.

5. Elevate the sight. Return it to horizontal with sufficient rapidity to approximate a maximum angular rate and lock it in that position.

6. Allow the reticle two minutes to settle following its movement down the scale. Using the elevation spot knob, move the reticle back to scale zero, the horizontal centerline of the scale.

7. Depress the sight as far as it will go; return it rapidly to horizontal, locking it in that position.

8. Allow two minutes for the reticle to settle after moving up the scale. Record scale reading (height of the dead zero area).

9. Using the elevation spot knob, adjust the reticle to the center of the area just determined. If the dead zero area as just determined exceeds seven mils in either train or elevation, the gun sight must be adjusted at a gun sight repair station.

GUN SIGHT MK 14 MOD 8

DEAD ZERO TEST

(Work Sheet)

Gun Sight Mk 14 Mod __________ Serial No. __________

Location ____________________

Test in Elevation

	Date of test run	Elevate sight, and record spot	Depress sight and record spot	Difference between readings (not to exceed 7 mils)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Total mils __________

Average mils __________

Test in Train

	Date of test run	Elevate sight, and record spot	Depress sight and record spot	Difference between readings (not to exceed 7 mils)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Total mils ____________________

Average mils ________________

RANGE SHIFT AND SUPERELEVATION TEST

The range shift and superelevation test is made to determine the amount of reticle movement in train and elevation when the range knob is shifted from median range to minimum range and from median range to maximum range.

Median range for each Mod of the gun sight is listed in OP 1040, page 86, table 3. The test should follow immediately after the dead zero test and be preceded by cyling the gun sight and checking the adjustment of the field test scale.

NOTE: The range shift and superelevation test is made with the gun sight in two positions of elevation: horizontal and elevated 60°.

1. Lock the director at zero train and elevation by use of the director locking pins.
2. Set the range knob to medium range, and allow the reticle to settle for two minutes.
3. Using the spot knobs, set the reticle center dot on scale zero. Record zero mils in train and elevation.
4. Shift the range knob setting to 400 yards, and allow the reticle to settle. Record the setting point in train and elevation.
5. Shift the range knob to maximum range. Allow the reticle to settle, and again record the settling point.
6. With the range knob still at maximum range, elevate the gun sight to 60 degrees, holding it in this position. Gun Director Mk 51 Mod 2 can be locked at this elevation. Allow the reticle to settle, and record the settling point in train and elevation.
7. With the gun sight still at 60° elevation, shift the range knob setting to median range, and allow the reticle to settle. Record the settling point in train and elevation.
8. Shift the range knob setting to 400 yards, allow the reticle to settle, and again record the settling point.

If for any shift of range (4, 5, 6, 7, and 8 above), the reticle movement is more than seven mils in train or is not within the limits in elevation shown in table 4, page 87, OP 1040, superelevation test limits, the gun sight must be adjusted at a repair station.

RANGE SHIFT TEST IN TRAIN

(Work Sheet)

Gun Sight Mk 14 Mod ____________________ Serial No. __________

Location ____________________________________

	Date of Dir. elev. test run	Set range to median, and record spot	Shift range to minimum, and record spot	Difference between readings (not to exceed 7 mils)
1.	0°			
	60°			
2.	0°			
	60°			
3.	0°			
	60°			
4.	0°			
	60°			
5.	0°			
	60°			

Total mils __________

Average mils __________

	Date of Dir. elev. test run	Set range to median, and record spot	Shift range to minimum, and record spot	Difference between readings (not to exceed 7 mils)
1.	0°			
	60°			
2.	0°			
	60°			
3.	0°			
	60°			
4.	0°			
	60°			
5.	0°			
	60°			

Total mils __________

Average mils __________

SUPERELEVATION TEST

(Work Sheet)

Gun Sight Mk 14 Mod. ____________________ Serial No. ____________

Location ____

Date of Dir. elev. test run	Set range to median, and record spot	Shift range to minimum, and record spot	Reticle movement (allowed ± 7 mils)
1. 0°			
60°			
2. 0°			
60°			
3. 0°			
60°			
4. 0°			
60°			
5. 0°			
60°			

Total mils ____________

Average mils ____________

Date of Dir. elev. test run	Set range to median, and record spot	Shift range to minimum, and record spot	Reticle movement (allowed ± 7 mils)
1. 0°			
60°			
2. 0°			
60°			
3. 0°			
60°			
4. 0°			
60°			
5. 0°			
60°			

Total mils ____________

Average mils ____________

DEFLECTION (SENSITIVITY) TEST

The Deflection, or Sensitivity, Test is designed to check the calibration of the sight by tracking a target on the Field Test Scale through an angle of 60° in train. The test should be made immediately following the completion of the Range Shift and Superelevation Test. A sample work sheet for recording test data is shown on the next page. Before proceeding with the test, first cycle the sight and correct the adjustment of the Field Test Scale if necessary.

To obtain the necessary 60° timing arc on the 20-mm antiaircraft gun, place two marks on the gun mount 60° apart. On Gun Director Mk 51 Mod 2, the 60° interval can be noted on the train scale.

1. Lock the gun in 5° elevation or gun director in zero elevation.
2. Set the range knob at the median range.
3. Starting to the left of the first mark, swing to the right fast enough to keep the reticle on the 100-mil dot to the left of scale zero. The reticle must be on the dot before the gun or director passes the first mark and remain on it until after the second mark is passed.
4. Start a stopwatch at the instant the gun or director passes the first reference mark and stop it just as the second (or 60°) mark is reached. Record the time interval.
5. Repeat steps 3 and 4, swinging the gun to the left while holding the reticle on the 100-mil dot at the right of scale zero.
6. Shift the range knob setting to maximum range. Repeat the test in each direction in train and record the times required.
7. Shift the range knob to 400 yards and again repeat the test in each direction in train, and record the results.
8. Repeat the entire test as described in steps 2 through 8 inclusive, moving the sight at a rate sufficient to hold the reticle on the 200-mil dot if possible.

If the times recorded do not fall within the limits given below for Mod 8 or for other Mods in OP 1040, the sight must be adjusted at a gun sight repair station.

Time (seconds) for 60° swing

	100-mil dot		200-mil dot	
Range	Min.	Max.	Min.	Max.
400	3.9	5.9	----	----
2000 (med)	24.8	32.9	13.2	15.2
3200	45.5	60.3	24.2	27.8

GUN SIGHT MK 14 MOD 8

DEFLECTION (SENSITIVITY) TEST

(Work Sheet)

Gun Sight Mk Mod ______________________ Serial No. __________

Location ______________________________________

100-mil dot
Minimum range

Date of test	Swing to right 60°	Swing to left 60°

1. ______________________________________
2. ______________________________________

Average time

Median range

1. ______________________________________
2. ______________________________________

Average time

Maximum range

1. ______________________________________
2. ______________________________________

Average time

200-mil dot
Minimum range

Date of test	Swing to right 60°	Swing to left 60°

1. ______________________________________
2. ______________________________________

Average time

Median range

1. ______________________________________
2. ______________________________________

Average time

Maximum range

1. ______________________________________
2. ______________________________________

Average time

CHARACTERISTIC TIME TEST

The Characteristic Time Test is designed to determine the time required for the reticle to return from some previously established initial deflection to 37 percent of that deflection. The characteristic time thus developed is a measure of the smoothing action of the gun sight, and must be controlled within definite limits in order for the sight to perform correctly. The initial deflection for this test is established at 210 mils, with 37 percent of initial deflection at 78 mils.

The Field Test Scale has four marks, each 210 mils from scale zero and four marks, each 78 mils from scale zero. These are the marks used in establishing the characteristic time of sight.

The characteristic time test should be made directly following the deflection test, and be preceded by cyling the gun sight and any necessary adjustment of the field test scale. It is recommended that the following work sheet for recording test data, or one similar to that shown is figure 100 in OP 1040, be used.

NOTE: During characteristic time test it is essential that the sight remain motionless while the observation of time is being made.

CHARACTERISTIC TIME OF TRAVERSE SYSTEM

Lock Gun Director Mk 51 Mod 2, at zero elevation. Set the range knob at maximum.

1. Swing the sight to the right through an arc of approximately 45°; stop the sight quickly, and hold it motionless. The reticle will be seen moving to the right from the left end of the scale.

CAUTION: SWING THE SIGHT ONLY RAPIDLY ENOUGH TO BRING THE RETICLE TO THE END OF THE SCALE. TOO RAPID SWINGING MAY DAMAGE THE GYRO UNIT.

2. Start a stopwatch when the reticle center dot passes the 210-mil mark. Stop the watch as the 78-mil mark is passed, and record the time interval.

3. Following the same procedure, swing the sight in the opposite direction, and record the characteristic time for the reticle moving from right to left.

4. Continue taking readings in alternate directions until a total of ten readings (five in each direction) have been taken. Average the time of movement in each direction, to minimize any personal error.

CAUTION: IF IT IS FOUND THAT THE TEN OBSERVATIONS OF TIME, TAKEN IN ANY RUN, DIFFER BY 0.4 SECOND OR MORE, THE FIGURES SHOULD BE DISCARDED. AFTER CHECKING THE SET-UP, A NEW RUN SHOULD BE MADE.

CHARACTERISTIC TIME OF ELEVATION SYSTEM

Lock the gun mount or gun director in zero train (fore-and-aft) and set the range knob for the maximum range for the gun sight mod being tested.

1. Depress the sight as far as possible, and allow the reticle to settle.

2. Return the sight rapidly to horizontal, and hold it motionless in that position. With a stopwatch, time the return of the reticle along the vertical centerline between the characteristic time marks. Record the time.

3. Elevate the sight about 60°; allow the reticle to settle, and repeat the foregoing procedure.

4. Repeat each of the above steps five times alternately, and determine the average time in each direction. Again, if the figures in the run differ by 0.4 second or more, they should be discarded and retaken after the test set-up has been inspected.

ALLOWABLE LIMITS OF CHARACTERISTIC TIME:

Table 6 of OP 1040 lists the allowable limits of characteristic time for the various mods of Gun Sight Mk 14. The Mod 8 limits are listed below. The limits given are for two different temperature ranges, room temperature and extreme temperature. The limits allowed for room temperature (65° to 85° F.) apply when the sight is being checked at a service station, provided the temperature is within those limits. When the sight is being checked aboard ship, or when the temperature surrounding the sight at the station is below 65°F. or above 85°F., wider tolerances must be allowed. The values for extreme temperature (0° to 100°F.) are then used.

Range Setting (yards)	Room Temp. (65°-85°F.)		Extreme Temp. (0° or 100°F.)	
	Min.	Max.	Min.	Max.
3,200	5.9	6.9	5.9	7.4

CHARACTERISTIC TIME TESTS

(Work Sheet)

Gun Sight Mk 14 Mod ______ Serial No. ______

Location ______ Date of test ______

Test in Elevation

Elevate sight to horizontal, and time reticle movement	Depress sight to horizontal, and time reticle movement	Time (not to vary 0.4 second or more from one to another)

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______

Note: ______ Total time ______

Take readings in alternate directions Average time ______

Test in Train

Swing sight to left, and time reticle movement	Swing sight to right, and time reticle movement	Time (not to vary 0.4 second or more from one another)

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________________________

Note: ______________________ Total time ____________

Take readings in alternate directions. Average time ____________

Characteristic time is the only performance test for which corrections can be made aboard ship.

Should the characteristic time test indicate that it is necessary to adjust a gyro unit thermoswitch, proceed as follows:

1. Remove the access plug at the rear of the sight. The plug for the traverse gyro is at the left and that for the elevation gyro at the right. A small pencil-type flashlight can be directed into the access hole to illuminate the adjusting shaft.

2. If the characteristic time is too short, turn the adjusting shaft clockwise to decrease the temperature of the gyro unit. If the characteristic time was too long, turn the shaft counterclockwise to increase the temperature.

3. Make the adjustment with the thermoswitch adjusting wrench provided with each Calibration and Training Fixture, turning the shaft only about 1/8 turn, a little at a time.

CAUTION: WHEN USING THIS WRENCH BE CAREFUL NOT TO MARK OR BURR THE RANGE ADJUSTMENT GEARS.

4. When the thermoswitch setting has been completed, replace the access plug, warm the sight for at least 10 minutes and conduct a characteristic time test.

If the air pump pressure gage is not at the proper valve, the discharge pressure can be corrected by adjusting the bypass valve as follows:

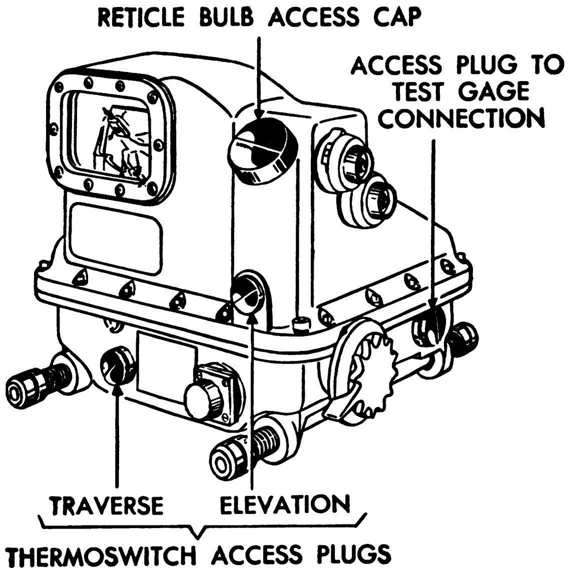
1. Make sure there are no leaks in the pressure hose.

2. Remove the cap over the adjusting screw in the pump head, and loosen the locknut.

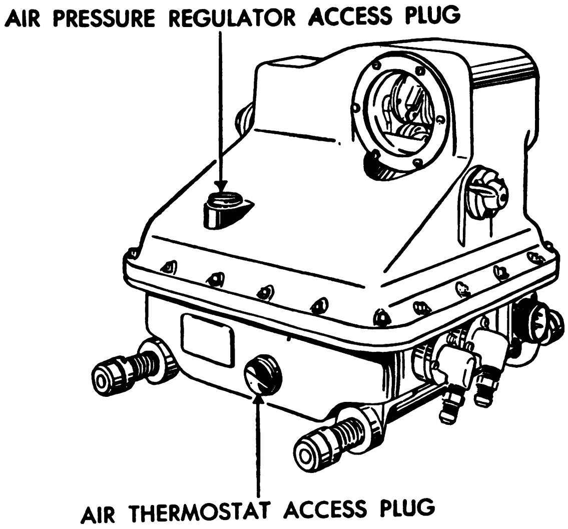
3. To increase the discharge pressure, turn the adjusting screw clockwise. To decrease the pressure, turn the screw counterclockwise.

4. Tighten the locknut and replace the cap.

Check the sight air pressure at least once every two weeks, or after every 200 hours of operation. Attach a portable test gage (BuOrd 325723--2) to the air pressure regulator test connection. This connection can be reached by removing the plug shown in the following figure. Be sure the gage is correct by checking it against a master gage. Check the pressure delivered from the power unit to see that it is correct.


RETICLE BULB ACCESS CAP
ACCESS PLUG TO TEST GAGE CONNECTION
TRAVERSE
ELEVATION
THERMOSWITCH ACCESS PLUGS

GUN SIGHT MK 14 ACCESS PLUGS
REAR AND RIGHT SIDE


AIR PRESSURE REGULATOR ACCESS PLUG
AIR THERMOSTAT ACCESS PLUG

GUN SIGHT MK 14 FRONT
ACCESS PLUGS

The correct pressure is 2½ psi (31 in. water at 68° F). When the pointer is in the green sector of the gage, the pressure is correct. If it is not, check hoses, air drier, and filter for restrictions. If no restriction is found, the air pressure regulator must be adjusted.

To reset the regulator, proceed as follows:

1. Remove the access plug. (See preceeding figure.)

2. Loosen the hexagonal locknut at the top of the regulators.

3. If air pressure is low, turn the adjusting screw clockwise; if air pressure is high, turn the screw counterclockwise.

4. Tighten the locknut and replace the access plug, making sure that the gasket is pulled up airtight.

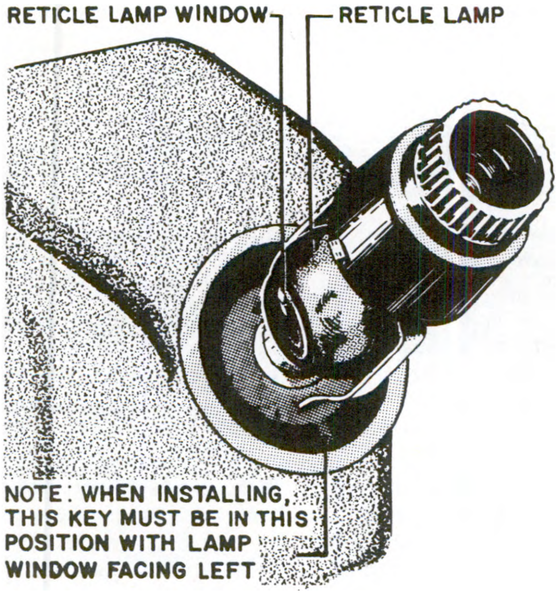
Check the reticle brightness by turning the reticle dimmer knob first to one, then to the other bright (BR) position. In each case, the reticle should come up to maximum brightness. If it does not, inspect the reticle lamp, and replace it if necessary.

Then, set the reticle to the required brightness.

Removal of the reticle lamp access cap (see previous figure) will expose the reticle lamp spring and cap assembly. To replace the lamp, remove this assembly from its housing as follows:

1. Push down on the assembly cap, and turn it counterclockwise as far as it will go and lift the assembly from the housing.

2. Remove the reticle lamp from its base by pushing the lamp down against the retaining spring, turning it counterclockwise and lifting it out.


RETICLE LAMP WINDOW
RETICLE LAMP
NOTE: WHEN INSTALLING, THIS KEY MUST BE IN THIS POSITION WITH LAMP WINDOW FACING LEFT

RETICLE LAMP REMOVAL

3. When placing a new lamp in the assembly, take care that the window of the lamp is faking 90° clockwise from the key on the base adapter. The correct position of the window is shown in the above figure.

4. When replacing the spring and cap assembly, locate the key on the lamp case so that it will slide into the corresponding groove on the lower side of the lamp socket; then, push down on the assembly cap and turn it clockwise as far as it will go.

5. Inspect the gasket on the reticle lamp access cap and renew it if necessary. Secure the access cap, making sure that the gasket is taken up airtight.

Lubrication of Gun Sight Mark 14 should be carried out once each week. Clean and grease with vaseline the two support rods on which the sight is mounted. Also apply vaseline to the shock absorber springs. This will minimize corrosion, and will prevent the support rods from freezing to the sight case and the gun sight bracket in cold weather.

Grease the threads lightly with vaseline at all electrical cable connections.

Apply a light coat of vaseline to the shaft of the power unit cut-out switch at the point where it passes through the stuffing box.

Remove the cap and adjustment screw of the bypass valve in the air-pump head. Apply a thin coating of vaseline to the threads of both the screw and the cap. After replacing the adjustment screw, start the power unit and check the gage pressure. If the pressure is incorrect, adjust the bypass valve.

All internal parts of the sight were adequately lubricated during assembly, and need no further lubrication. No lubrication should be attempted except during overhaul at a service station.

Check the air dryer once each week. Remove the drier from its housing on the power unit for the purpose of observing the condition of the silica gel.

To remove the drier, first take off the two nuts holding the access cover on the drier, and remove the cartridge from its housing.

The color of the silica gel indicates whether or not it needs replacing. If the silica gel is blue, it is still dry and need not be replaced. If the silica gel has changed to a pink color, the material is wet and should be activated. In the latter case, unscrew the cartridge from the access cover and renew it with a spare, dry cartridge.

When renewing the drier, check the condition of the internal and external gaskets, and renew them if necessary. Make sure that the internal gasket is correctly placed in the drier housing, so as to make an airtight joint when the access cover is put in place.

Silica gel cartridges which have been removed because of saturation, should be stored in a dry place until they can be activated.

To activate the silica gel, place the cartridges in an oven heated to between 275° and 300° F. The oven temperature should never be allowed to rise above 300°F., or the drier may be damaged. The cartridge should be left in the oven from four to five hours, or until the silica gel regains its blue color. The activated cartridges should immediately be placed in airtight containers and stored until needed.

At times, silica gel turns brown when being activated. This may be caused by carbonization of accumulated salt or oil. Such a condition will not impair the dehydrating properties of the material, but may make its color change indications unreliable. Cartridges in this condition should be refilled with silica gel at a repair station.

SECTION IX

TOPIC 4

SOUND-POWERED TELEPHONES

A. You have learned:	References:
1. About fire control in general	
2. About basic electricity and electronics	
3. About safety precautions	
4. About basic hand tools	
5. About Amplidyne Power Drive Mk 4	
6. About Gun Director Mk 51 Mod 2	
7. About Gun Sight Mk 14 Mod 8	
B. You are learning:	
1. About shipboard communications	NavPers 16116-B, pages 706 to 712
	TTM, pages 2-3, 6-9
2. About sound-powered telephones	NavPers 10164-A, pages 195, 198-202
3. Types of sound-powered telephone circuits	TTM, pages 24-27 NavPers 10164-A, pages 195-198
4. How to wear and secure sound-powered telephones	TTM, pages 9-19 NavPers 10164-A, pages 202-208
5. Telephone talking procedure	TTM, pages 20-23, 27-40 NavPers 10164-A, pages 208-211
6. About the care and maintenance of sound-powered telephones	
C. You will acquire skill in:	
1. Sound-powered telephone talking	
2. Handling and securing sound-powered telephones	

SHIPBOARD COMMUNICATIONS

Aboard ship there are numerous communications systems for transmitting and receiving orders and information. Although the maintenance of these interior communications systems is not the responsibility of FT's, they are of primary interest to the Gunnery Department. The following systems are the ones most likely to affect your shipboard life and duties.

The sound-powered battle telephone system is the most important. In this system the energy that creates the current which transmits the message is supplied entirely by the speaker's voice. Since no outside source of power is required, this system is more reliable in emergencies than is any other system. Because of the importance of this system, this topic will cover the proper care and use of sound-powered telephones.

Another communications system you may see is the Ship's Service Telephones. This system will be found on the larger ships, and operates like the conventional dial telephone systems found ashore. It is electrically powered, and has a central switchboard and dialing apparatus for making connections between stations. Because in general only two stations can be on one circuit at one time, and because the system is vulnerable to power failure, the ship's service telephone system is not to be depended upon under battle conditions.

Other communications systems requiring an outside source of electrical power are the Battle Announcing Systems. The principle systems that you will see and use aboard ship are:

1. The General Announcing System, 1MC

   This is the main announcing system for the ship, operating under the authority of the Officer of the Deck, over which word can be passed to all parts of the ship.

2. The Dual-purpose Battery Announcing System, 17MC

   This system provides for transmission of gun control orders from dual-purpose battery director stations to dual-purpose gun mounts.

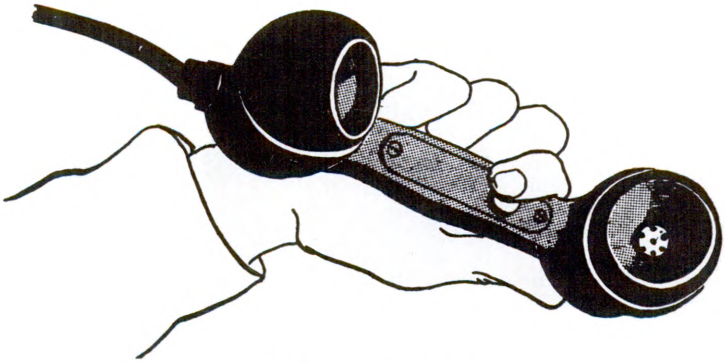
3. The Captain's Command Announcing System, 21MC

   This system provides for two-way transmission of ship control orders and information between interested key stations.

Ships still use the oldest interior communications device, the voice tube. It has its limitations as to maximum practical length, and its efficiency falls off rapidly every time the tube goes around a corner, but it is simple and reliable. Voice tubes are rarely used below decks, as they seriously impair watertight integrity.

SOUND-POWERED TELEPHONES

There are two types of sound-powered phone sets, the handset and the headset. The handset telephone looks like a "French-type" telephone, except that in the middle of the bar connecting the transmitter and receiver is a pushbotton which must be held down whenever the user is speaking or listening. This instrument is used as an emergency phone and also as a service phone (on supplementary circuits) in such places as the bridge, the wardroom, and ship's offices.



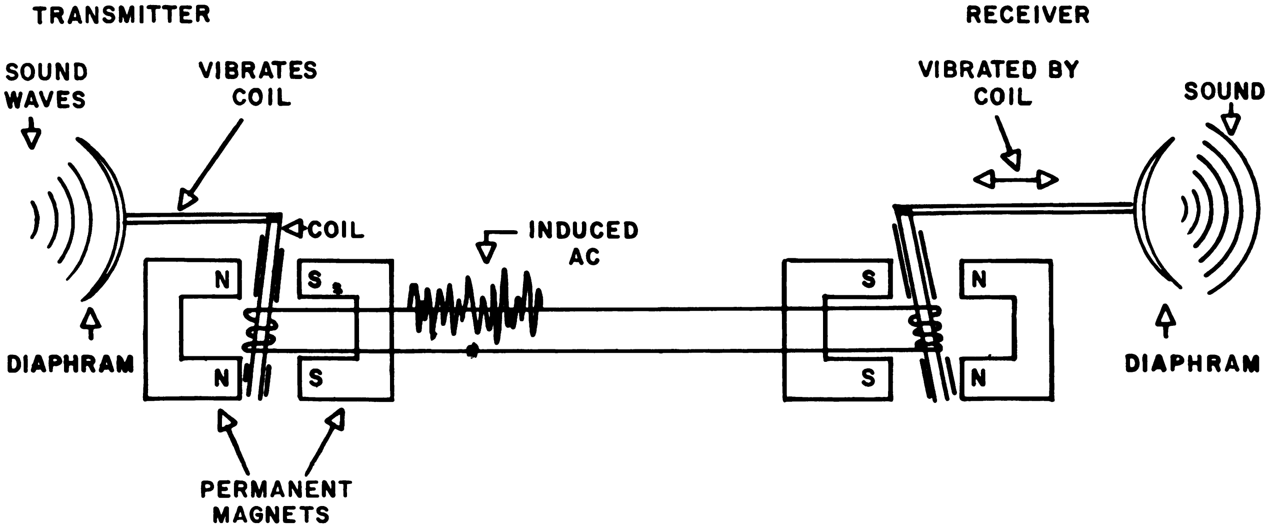
SOUND-POWERED TELEPHONE HANDSET

The headset telephone is the standard battle telephone. It consists of a pair of earphones and a transmitter. The earphones are on a spring-metal clamp or fabric harness that fits over the talker's head. The transmitter, held in an adjustable yoke, is mounted on a breastplate. The breastplate is hung on a strap around the talker's neck. Also, there is on the breastplate a small box where the wires are joined together. One of the leads is short and goes to the mouth piece. The other two leads go to the earpieces. Connected to the breastplate is a long, heavy lead, at the end of which is a metal plug to be inserted into the appropriate jack box to connect the phone to the rest of the circuit. In case of a casualty to the transmitter on a headset phone, it is possible to speak into one earpiece, while listening through the other.

Essentially, the sound-powered telephone instrument consists of a diaphragm, an electromagnetic unit, and a framework which supports both the diaphragm and the motor. When the electromagnetic unit is used as a transmitter, it acts like a generator; used as a receiver, it acts like a motor. For convenience of the user, the handsets and the headsets are equipped with separate instruments for transmitting and receiving. In principle, however, the instruments themselves are the same. The arrangement of the housing surrounding the diaphragm of the instruments is somewhat different in the two cases so that the instrument may perform the service for which it is intended in the best possible way.

The armature of the electromagnetic unit is located between the pole tips, one pair at each end of the armature and on opposite sides. The spacing between the pole tips at each end of the armature is such that an air space is charged with a very intense magnetic field. The magnetic field is supplied by the two permanent magnets which are held in contact with the pole tips.

When sound waves strike the diaphragm, the armature is set into vibratory motion. This movement of the armature causes an alternating polarizing flux to pass through, and consequently an electrical a-c voltage is induced in the coil surrounding the armature. The frequency and the waveform of the induced voltage in the coil is the same as that of the sound wave impinging on the diaphragm. Thus, acoustical power is converted into electrical power.



On the other hand, if an alternating current is passed through the coil, it will cause an alternating flux to pass through the armature. The interaction of this alternating flux with the polarizing flux of the permanent magnets generates on the armature mechanical forces which are transmitted through the drive road to the diaphragm. The diaphragm vibrates accordingly and generates sound waves. Thus, at the receiver, electrical power is converted into acoustical power.

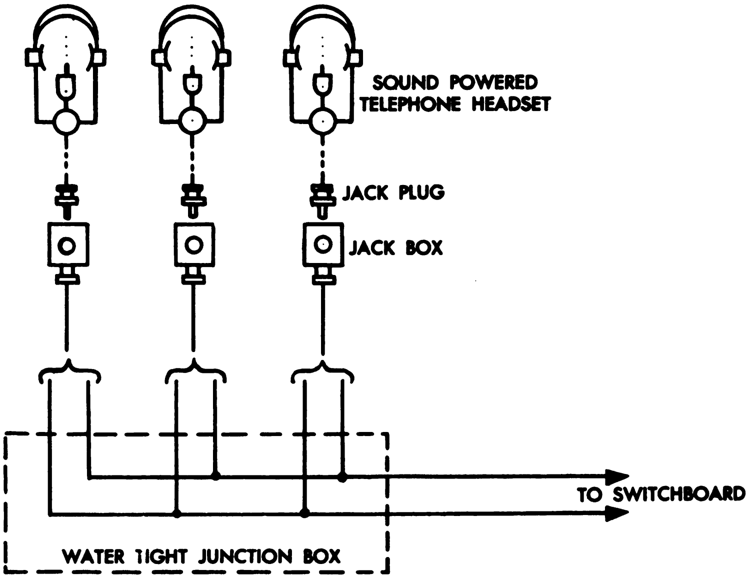
Examining the construction of the unit, you will find that the magnetic field around the armature is so intense that the proper location of the armature in the air gaps is important in obtaining the highest possible efficiency. Normally, the average position of the armature should be exactly halfway between the pole tips. On those rare occasions when the armature becomes off-center, it should be adjusted to its normal position by regulating the position of the nuts connecting the armature to the drive rod. Special wrenches must be used for this operation.

The polarizing magnets are made of the best grade of alnico (an alloy of metal) and will maintain their charge indefinitely if left undisturbed. However, if they are taken off the assembly and replaced a number of times, they will lose some of their magnetism.

TYPES OF SOUND-POWERED TELEPHONE CIRCUITS

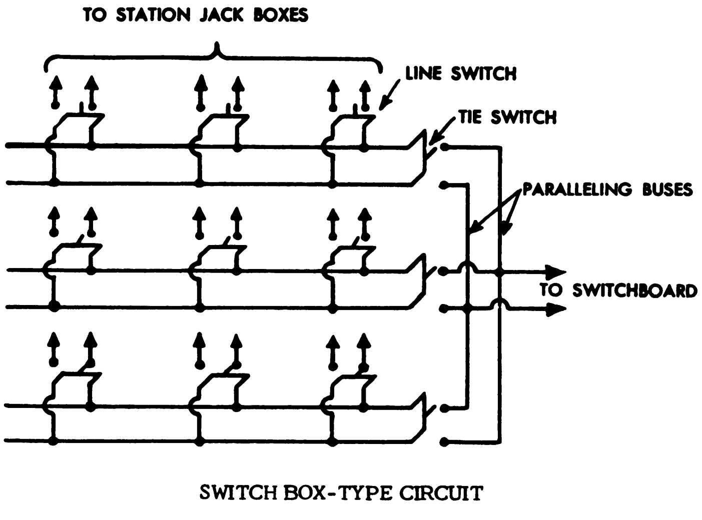
Battle telephone circuits are composed of three types, based on the methods of switching used. These are the STRING-TYPE CIRCUIT, SWITCHBOX CIRCUIT, and the SWITCHBOARD-TYPE CIRCUIT.

The string-type circuit is shown in the following figure. Here the outlets of a group circuit are connected in parallel with no facilities for switching between the phones within the group. This circuit is used where there are only 8 to 10 outlets within the group.



STRING-TYPE SOUND-POWERED TELEPHONE CIRCUIT

The switchbox-type circuit is used where a station such as the main battery plotting room is subdivided into several groups. In this set-up, all phones are fed from a watertight (WT) box as shown in the following figure. A study of the diagram will show that any one phone can be isolated from its group by opening a line switch. At the left of the drawing the buses of each group can be tied into a common bus (running vertically) by a tie switch. When all tie switches are closed, all groups are paralleled.



SWITCH BOX-TYPE CIRCUIT

Where a string circuit or a switchbox circuit is to be connected for communication with other groups or stations, it is fed into a switchboard where cross connections between groups can be made by an operator.

Large ships have battle telephone switchboards for main battery, secondary battery, antiaircraft battery, and ship control. Of course, whenever it is necessary, the various switchboards can be cross-connected by different switching combinations, thereby enabling parties of different batteries to communicate.

As you might guess, each of these battery systems is divided into groups, and each group may compose a string circuit or a switchbox circuit such as Main Battery Radar No. 1 or Main Battery Rangefinders, Group 1. Also, each group is assigned circuit letters from JA to JZ and each outlet on a circuit is assigned a number. For example, the captain's battle circuit (JA) would have group circuit numbers ranging from JA1 to JA10.

Located on battle telephone switchboards are line switches and jacks for each group. The purpose of the line switch is to either connect or disconnect a single talking station from its group. The jack is for the purpose of either paralleling the phone with another group or paralleling two groups. If the line switch is opened, a station may be disconnected from its group and then can be connected to any other group by a PATCHING CORD, which is a short flexible cord with a plug as each end. If the line switches are left closed, entire groups can be paralleled with a patching cord.

Also located on the switchboard are tie switches which provide a way to parallel entire groups. Then too, transfer switches of the rotary type are provided for quickly disconnecting a number of phones from one station and connecting them to another. As you know, a rangekeeper of a main-battery system can be connected to any gun or to any director of the battery. In turn, communications lines must be rearranged for each set-up, and transfer switches do the job.

The jack boxes of certain control officers' phones are connected to selector switches which enable the officers to cut in on any group under their control or on other primary circuits so that they may either issue orders or monitor conversation. A couple of examples of this set-up is the selector switch which enables the captain's talker to switch to the captain's battle circuit (JA circuit), or the gunnery officer's selector switch which enables him to switch from his own circuits to CIC, the air defense circuits, or the captain's battle circuit.

WEARING AND SECURING THE HEADSET

Too much stress cannot be laid upon the proper care and handling of the sound-powered telephone headset. Although these telephones are comparatively rugged, there are certain forms of abuse which manufacturers find practically impossible to guard against. It is reasonable to expect that the most vulnerable parts of any portable electric equipment are the connecting cords. Telephones are no exception. The most common troubles which occur in headsets are breaks in the wires running from the chestplate junction box to the transmitter and receivers. Also, the lead cord gives trouble by breaking at the chestplate junction box or at the jack plug on the other end.

When you pick up the set before putting it on, hold the entire set carefully in your left hand. You will find the headpiece is hung over the transmitter's supporting brackets and that the lead cord is coiled.

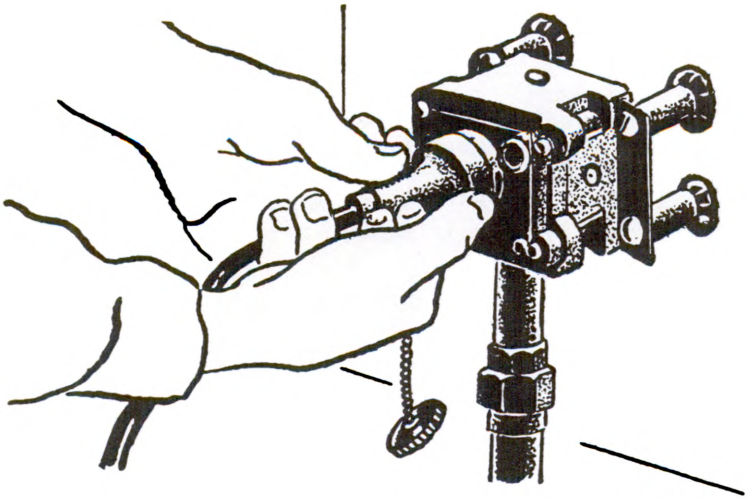
To put the headset on, you must first unhook the right side of the neck strap from the chestplate, put the strap around your neck, and then fasten it to the chestplate again. Second, put the earphones on and adjust the headgear so that the centers of the receivers are directly over the openings of your ears. Then test the phone and insert the plug into the jack box, screwing the collar on firmly by gripping the plug.

Adjust the mouthpiece so that it is directly in front of your mouth, when you stand erect. When you speak into the transmitter, it should be about ½ inch and never more than 1 inch from your mouth. In making this adjustment, remember that the fine wire that goes to the transmitter can easily be broken. Be sure that there are no sharp bends in it, and do not allow it to get caught between the transmitter and mounting brackets. An Electrician's Mate on almost any ship will tell you that he has several phones to repair every day just because talkers are careless in handling the phones.

When you are wearing the phones, remember that you can't walk any further than the length of the cord. If you do, you may break the connection at the jack plug or at the junction box. Therefore, always keep some slack in the lead cord, and be sure it is flat on deck so that no one will trip over it. Do not allow objects to roll over the lead.

Before plugging into the jack, give your phones the BLOW TEST. To do this hold the transmitter button down and blow into the mouth piece. If you hear a "SH-H-H" sound in the receivers, you know your phones are working. If the phones are not in order, take them to the man in charge of your station. When that is not possible, another talker near you can report the matter to the control station. Phones that are out of order may prevent other phones on the circuit from working properly, or kill the circuit entirely. Never stow damaged phones--take them to the Electricians' Mate for repairs. You never know when an emergency may require the use of every phone on the ship.

Never secure the phones until you have permission to do so. When this permission has been given, you are ready to make up the phones. The phones will make up somewhat differently for various methods of stowage, but the following method will suit most conditions.



USE BOTH HANDS TO RELEASE THE PLUG FROM THE JACK BOX

First, remove the plug from the jack box by holding the plug in one hand and unscrewing the collar with the other as shown in the above figure.

When the collar is loose, grasp the plug and pull it out. Never pull it out by the lead because that will break the wires. When the plug is out, lay it on the deck, being careful not to drop it. If the cover is left off, salt air, dust, and dirt will soon cause a short circuit or a bad connection in the jack box. If you see an uncovered jack box, cover it even though you were not responsible for leaving it open.

Second, remove the headgear and hang it over the transmitter yoke (supporting brackets).

Third, let the plug lie on the deck, and coil the lead cord. Start coiling from the end at the phone, and leave the rest of the cord on the deck. Coil the lead in a clockwise direction, holding the loops in one hand. The loops should be 8 to 10 inches across, depending on the size of the space where the phones are to be stowed. When you are coiling the lead, be careful not to bang the plug against the bulkhead or deck.

Fourth, when the lead is coiled, remove the earpieces from the transmitter yoke and put the headband in the same hand with the coil. Use this same hand to hold the transmitter while you unhook one end of the neckstrap from the chestplate. Fold the transmitter supporting yoke flat, being very careful not to put a sharp bend in the transmitter cord.

Fifth, bring the back of the chestplate together with the headband and the lead wire coil. Then secure the headband and coil together by winding the loose end of the neckstrap around the coil and the headband. Wind just enough times so that there is a short end left over. Fasten this end back on the chestplate as shown in figure 6-9. You then have a neat, compact package to be stowed.

Finally, put the telephones into the box, or hang them on the hook provided for them. Be careful not to crowd or jam the leads. It may be necessary to place the transmitter back against the chestplate before stowing the phone in a box.

Remember that the phones must be unplugged no matter what method is used to secure them. Phones that are left plugged in will pick up noise through the earpieces and carry it into the circuit. A most careless act is that of placing the phones on the deck. Not only is it possible for someone to step on them, but all the surrounding deck noises will enter the phones with great force. See to it that you never allow this to happen. Always handle phones with care as they're a vital link in controlling your battery.

TELEPHONE TALKING PROCEDURE

The power generated by a sound-powered telephone is proportional to the strength of the sound waves impinging on the diaphragm. For that reason you must give particular attention to how you speak into the phone. Talk in a medium-loud voice at a consistent level so that every word will get through to all stations on the circuit. It is also important to have your mouth close to the transmitter. If your mouth is $\frac{1}{2}$ inch from the transmitter, a message will ordinarily get through, but at 4 inches, less than half of your message will be heard correctly.

You must also pronounce and enunciate words properly. This means moving the lips and the tongue so that each sound is made correctly and distinctly. For example, when you say ''oh'' your lips should be definitely rounded. An ''ee'' will be clearer if the lips are pulled back at the corners. You must always guard against dialect, by using standard American pronunciations. Be sure to pronounce each syllable with care and make every part of the message stand out so that even unfamiliar words may be understood by the listener.

Numbers are especially difficult to understand over the telephone when they are not spoken properly. Careful study of the pronunciation of numbers indicates that the following exaggerated pronunciations are highly desirable:

1	Wun
2	Too
3	Thuh-ree
4	Fo-wer
5	Fi-yiv
6	Six
7	Seven
8	Ate
9	Niner
0	Zero (in certain ordnance communications this is pronounced OH)

Standing a phone watch is not always exciting. You may stand with the phones on for several minutes or even hours at a time and perhaps no important messages will be passed over the circuit. Under these circumstances it is easy to get careless and take part in private conversation with someone else on the line. Recordings made on board ship show that several talkers may take part in such a conversation and because of all this unnecessary talking there is the danger of delay when an important message comes through.

As a talker, you are a link in the interior communications chain which, like any other chain, is no stronger than its weakest link. Unauthorized talking means that there are at least two weak links in the chain. If someone else on your circuit persists in useless talking remind him to keep the line clear so there will be no delay when a message must go through.

Circuit discipline also means that the talker must never show impatience, anger, or excitement. He must talk slowly, in a loud, clear voice. Circuit discipline means SELF-DISCIPLINE.

In general, the duty of a talker is to pass along a message exactly as it is given to him, adding only the station identification. If he changes the wording he may give the message a meaning that was not intended by the originator (an officer or senior Petty Officer). Some of these mistakes have had serious consequences.

Sometimes, in the absence of an officer or senior PO, the talker will have the responsibility of originating the message himself. When this responsibility has been delegated to him he must be careful to follow correct procedures. Standard procedure and standard commands have been established in nautical terms so that information can be transmitted accurately and rapidly. You'll learn how to follow this procedure only through practice and instruction on the job.

CARE AND MAINTENANCE

In order that sound-powered telephone equipment may be ready for any emergency, it must be kept in good condition and handled properly at all times. Defective phones must be repaired as soon as possible and not allowed to collect. Maintenance of the phones is usually the responsibility of the I.C. electrician aboard ship.

SECTION IX

TOPIC 5

GUN FIRE CONTROL SYSTEM MK 51

A. You have learned:	References
1. About fire control in general	
2. About basic electricity and electronics	
3. About safety precautions	
4. About basic hand tools	
5. About Amplidyne Power Drive Mk 4	
6. About Gun Director Mk 51 Mod 2	
7. About Gun Sight Mk 14 Mod 8	
8. About sound-powered telephones	
B. You are learning:	
1. Inter-relationship of the major units of the GFCS Mk 51	OP 821-A, page 30 NavPers 10171, pages 221 to 224 NavPers 16116-B, pages 613, 614, 623, 624
2. Operation of the system	OP 821-A, pages 122 to 123 OD 4424, pages 15 to 18 NavPers 16116-B, page 624
3. Preventive maintenance to be conducted on the GFSC Mk 51	OP 821-A, pages 210 to 222 OD 4424, pages 19 to 24 CDP 0-514 CDP 0-514a CDP 0-539a

C. You will acquire skill in:

1. Procedures for conducting some of the maintenance on the system

INTER-RELATIONSHIP OF THE MAJOR UNITS

Up to now, as you studied this section, you have learned about Amplidyne Power Drive Mk 4, Gun Director Mk, 51, and Gun Sight Mk 14. These equipments, with the gun mount, are the major units of the GFCS Mk 51. You also learned about the means of communication employed aboard ship.

You studied each equipment individually. However, in actual practice, the proper operation of each is dependent on the operation of the others. If any equipment does not function properly, the accuracy of the GFCS Mk 51 is greatly affected. There is another factor that affects the accuracy of the system. It is the ALIGNMENT of each equipment to the others. This alignment will be taken up in the next section of this course.

When you studied the fire control problem, you found that a moving target must be LEAD. This was called "lead angle" and was broken up into two components; the "train lead angle" and the "elevation lead angle." These lead angles are accurately developed by the proper operation of Gun Sight Mk 14. The Gun Sight also establishes the line of sight to the target which is combined with the lead angles to compute the line of fire.

The train and elevation angles to the line of fire are measured by the position of Gun Director Mk 51. These angles are called "gun train order" and "gun elevation order," and are used to position the rotors of the synchro-transmitters in the director. These "orders" are converted to electrical signals by the synchro-transmitters, and sent to the control transformers at the gun mount.

Power Drive Mk 4 uses the "gun train order" and "gun elevation order" received at the CT's to correctly position the gun mount along the line of fire. This happens when the power drive is operating in AUTO. In case of emergency, or other reasons, the mount may be positioned with the power drive in LOCAL or MANUAL. However, maximum accuracy is obtained when it is operated in AUTO.

Thus, you can see, the accuracy of the GFCS Mk 51 is dependent on the proper operation of each of the units in the system, and the proper alignment of the units to each other.

OPERATION OF THE SYSTEM

The GFCS Mk 51 is normally operated with Power Drive, Mk 4 in AUTO. When this condition is met, all units of the system will be in use, and the accuracy of fire will be the greatest.

Before the system can be operated, the gun sight must be energized and warmed up. After the sight is warmed up, it must be properly checked out.

When operating the system, there are several important points to remember.

1. The generated load angles are correct only if:
    a. the tracking rate is smooth,
    b. the range setting is correct, and
    c. spots are properly introduced.
2. The spot knobs on the sight should be used only for the correction of obvious errors in alignment.
3. Whenever slewing from one target to another, the caging switch must be closed.
4. The power drive should be in AUTO.
5. The firing should be controlled by the director pointer.

PREVENTIVE MAINTENANCE

Preventive maintenance is used to keep an equipment operating. The idea behind preventive maintenance is to prevent casualties from occurring and to spot any casualty as soon as it occurs. Preventive maintenance includes all routine tests, checks, adjustments, and lubrication.

To insure that the preventive maintenance of the GFCS Mk 51 is properly and completely carried out, check-off lists for the equipment are provided. These lists include the tests, checks, etc., and the frequency at which they are carried out. They provide a visual record of preventive maintenance.

Some of the check-off lists should become familiar to you. They are:

1. Mk 14 sight and Mk 51 director, routine upkeep CDP 0-539a (Rev. 1-54)
2. Machine gun battery (heavy), Pre-firing check-off (FC) CDP 0-514 (Rev. 8-50)
3. Machine-gun battery (heavy), Post-firing check-off (FC) CDP 0-514a

There are numerous other check-off lists. Some of these other lists are used instead of those given above. Whichever lists are available, they should be followed thoroughly and kept up to date.

SECTION X

FIRE CONTROL MAINTENANCE

Topic No.	Topic Title	Sheet
1.	Battery Alignment	X-1-1
2.	General Maintenance	X-2-1
3.	Fire Control Circuit Maintenance	X-3-1

SECTION X

TOPIC 1

BATTERY ALIGNMENT

A. You have learned: References:

1. About fire control in general
2. About basic electricity and electronics
3. About the use of tools
4. About general safety precautions
5. About gun fire control system Mk 51

B. You are learning:

1. Alignment of GFCS Mk 51

OD 4429, pages 22-23
OD 4424, pages 11-12
TraPac 101, pages 153-155
OP 1040, pages 95-100

C. You will acquire skills in:

1. Aligning the GFCS Mk 51

ALIGNING GUN FIRE CONTROL SYSTEM MK 51

Alignment of the weapons in his charge is one of the most important features of the fire controlman's job. A man may make a fine showing at keeping his gear clean and spotless. He may be excellent at troubleshooting and repair. But if his equipment is out of alignment and he doesn't know it, or if he suspects it and does nothing about it, he might just as well have never fixed that last casualty. For without a working alignment no piece of fire control equipment even approaches its battle efficiency.

The alignment problem could be a very complex one. The more pieces of different equipment, the more involved becomes the alignment problem. We have a fairly simple system in Gun Fire Control System Mk 51 and, therefore, our alignment problem will be a simple one.

PROCEDURE FOR ALIGNING THE GUN FIRE CONTROL SYSTEM

First you must make sure that the synchros are accurately aligned. The procedure for checking the alignment of the synchros may be found in Section VI, Topic 9.

Next we will align the Gun Sight Mk 14 to the director bracket holes, as follows:

1. Select a well-defined target at about 2000 yards and at the midpoint of gun train to minimize parallax.

2. Insert boresight tube in right-hand sight bracket holes.

3. Turn on air supply switch and allow sight to warm up for at least 30 minutes.

4. Set reticle brightness control knob so that the reticle within the sight is plainly visible.

5. Set deflection spot knob to zero and elevation spot knob to 15 mils down (to cancel superelevation correction).

6. Set range handle to medium range (2000 yds).

7. Cycle sight in train and elevation about the target.

8. Sight through the boresight tube on target and observe target's position in regard to the reticle.

9. At this time the boresight tube and reticle should be on target. If they are not on the same target, adjust the reticle to correspond with the boresight tube by means of the spot knobs.

10. If the spot knobs were moved, they must be readjusted to zero. This is done by loosening the one or three screws (depending on the type of spotting knobs) and move knob and index plate together to their original position.

11. Recheck reticle against boresight tube on director.

PROCEDURE FOR ALIGNING THE GUN TO THE DIRECTOR

1. Put the boresight in designated barrel of 40-mm gun. Light off mount in train and elevation and place drive in automatic.

2. Sight through boresight tube on a target of at least 1000 yards. At this time the target should also be centered in boresight of the gun.

3. If boresight of gun is not on target, loosen the adjustable couplings (1 each for train and elevation) and move the response gearing until gun converges on target as seen through boresight tube at the director.

4. Tighten adjustable coupling and recheck adjustment.

5. Secure gear and boresight equipment.

SECTION X

TOPIC 2

GENERAL MAINTENANCE

		References:
A.	You have learned:	
	1. About fire control in general	
	2. About basic electricity and electronics	
	3. About safety precautions	
	4. About basic hand tools	
	5. About the CFCS Mk 51 and its component equipments	
	6. About battery alignment	
B.	You are learning:	
	1. About maintenance in general	BuOrd Manual, Chapter II. NavPers 10164-A, pages 246, 247.
	2. About moisture, cleaning, and Lubrication	NavPers 10164-A, pages 247-250.
	3. About maintenance routine	NavPers 10164-A, pages 250-251.
	4. About fire control tests and checks	NavPers 10164-A, pages 254-263.
	5. About repair and painting	NavPers 10164-A, pages 251-253.
	6. About spare parts	NavPers 10164-A, pages 253-254.
	7. About cleaning and care of optics	NavPers 10164-A, pages 263-265.

MAINTENANCE IN GENERAL

Fire control instruments are high-grade precision equipment and must be given proper care and lubrication. Undue wear on the equipment should be avoided by correct usage. Correct operation, handling, and care will go a long way toward increasing the life of fire control gear.

You, as a Fire Controlman, will find that your most important job will be the operation and routine maintenance and tests of the equipment on your ship. Under normal circumstances you will be under the direction of a senior petty officer; however, since this is not always the case, a good man must be able to take over at any time in matters of routine. That is why the following is directed to you as though you were ''it.''

Detailed description and instructions as to the correct installation, operation, lubrication, care, and upkeep of fire control equipment are contained in ordnance pamphlets, ordnance technical instructions, and Bureau of Ordnance circular letters. The following additional general rules are essential to maximum operating efficiency and minimum maintenance.

1. Every Fire Controlman shall be thoroughly acquainted with the detailed operational and maintenance instructions contained in ordnance publications applicable to the equipment in his battery.

2. All instruments shall be inspected periodically, including those in spare parts. Instructions for this inspection of instruments in store are issued from time to time by the Bureau of Ordnance in the form of circular letters.
3. Spare parts and instruments shall be stored in dry, dust-proof compartments to insure protection from weather as well as from examination by unauthorized persons.

The above is based on excerpts from the Bureau of Ordnance manual. It is strongly recommended that you take the time to read chapter II of this manual.

MOISTURE, CLEANING, LUBRICATION

The first item to be mentioned here is moisture. The battle against moisture is never ending, but the results will be more satisfactory if a few simple precautions are taken. Moisture carried by salt air creeps into the smallest openings and causes corrosion of the worst kind; so always keep watertight covers in place. This means keeping covers and protective canvas on in foul weather. Even inspection covers should not be removed in damp weather unless it is absolutely necessary. Keeping electrical circuits energized during periods of extreme dampness will help to reduce the amount of moisture they absorb.

Secondly, keep your equipment clean and free of dirt or other foreign matter. This will reduce the changes of corrosion. Also, oil and grease cause deterioration of electrical insulation, with consequent grounds and other electrical trouble.

The third item to be considered here is lubrication. Much of the lubrication required for fire control equipment is for the purpose of preventing rust, oxidation, and corrosion. However, its prime purpose is that of reducing friction between moving parts. Oil and grease are normally used sparingly because too much lubrication can be harmful to electric wire insulation and gasket material. For this reason, instruments should be wiped free of oil periodically to reduce the collection of grit and dirt. Ordnance publications applicable to the particular equipment under consideration will tell you when to lubricate, what type of lubricant to use, how much to use, and where to put it.

The types of lubricants used are referred to in OP's by Bureau of Ordnance specification numbers. These specifications are often changed from time to time by direction of Bureau of Ordnance circular letters. For example, a circular letter may direct that lubricant specification "so and so" used on certain equipment should be discontinued, and that you should shift to the lubricant specified in the letter. This you do. Sounds funny? No, it means the Navy has developed a better lubricant for the particular use. Thousands of dollars have probably been expended developing this new lubricant, and it has proved more suitable than the one it replaces.

The following circular letter was taken from the Navy Department Semimonthly Bulletin, dated 21 July 1947. This type of letter keeps your gunnery officer up to date on changes and improvements in lubrication techniques. Read it carefully as it contains valuable information on the latest types of lubricants, and the places used.

CIRCULAR LETTER F3-47

47-742--LUBRICATION OF FIRE CONTROL INSTRUMENTS FOR SERVICE USE AND FOR LONG-TERM STORAGE (Mn4), 21 July 1947

ACTION: ALL SHIPS AND STATIONS

(Ref.: a. Instrument Oil, BuOrd Specification 14-9-20 (Ord) (formerly OS1647), standard stock No. 14-9-975-25.
b. Instrument Grease, BuOrd Specification 14-G-8 (Ord) (formerly OS1648), BuOrd Specification 14-G-10 (Ord).
c. Bearing Grease, BuOrd Specification 14-G-10 (Ord) (formerly OS1350), standard stock No. 14-G-715 or 14-G-720.
d. NavOrd List No. 19742, Lubricants for Ordnance Equipment on Naval Vessels.)

1. The Navy has recently developed two synthetic lubricants, references (a) and (b), for general-purpose lubrication of instruments. These new lubricants have excellent rust inhibitors and antioxidants, a wide operating temperature range, and extremely low rate of evaporation. These combined properties provide an oil and a grease for general use in ordnance instruments that is very superior to the numerous other lubricants now in use.

2. It is requested that as soon as availability of supply permits, lubricants, references (a) and (b), be used in place of the various previously prescribed proprietary and specification lubricants for light fire-control instruments within the following limitations.

   a. "Light Fire-Control Instruments" are to be considered as those containing synchros, gyros, computing mechanisms, control devices, and other lightly loaded mechanisms. Examples of mechanisms which would be lubricated with the synthetic instrument oil and grease are as follows:

      Ring dial bearings
      Small shaft bearings
      Synchro stator and rotor bearings
      Integrator bearings and disc
      Lightly loaded gears
      Multipliers
      Slides
      Pivots
      Component solvers
      Limit stop screws

   b. The choice of oil or grease in the lubrication on any particular piece of equipment shall be determined by the type of lubricant previously prescribed; that is the instrument oil, reference (a), shall be used where oil was specified and instrument grease, reference (b), shall be used where grease was specified on the applicable lubrication charts or other prescribed lubrication instructions.

   c. Suitable synthetic lubricants are not presently available for heavy load applications, high temperature applications, extreme pressure applications, or for watch and clock mechanisms. Pending availability of more suitable synthetic lubricants, use of presently prescribed lubricants shall be continued in fire control equipment for the following applications, with exception of those lubricants specified in paragraph 4 below:

      1. Heavily loaded gears and bearings
      2. Electric power motors
      3. Gear boxes and heavy shafting
      4. Heavy-duty roller paths
      5. Gyro wheel and bearings
      6. Watch and clock mechanisms

3. Instrument oil, reference (a), is now available in standard stock, and vessel allowances are contained in reference (d). Instrument grease, reference (b), is not immediately available in standard stock, but is under procurement and when available in the near future will be added to allowance list, reference (d). Pending its availability, bearing grease, reference (c), should be used as a substitute therefor.

4. Certain proprietary lubricants have been found to be deficient in oxidation stability to the extent that their failure in storage due to oxidation would be probable. Accordingly, it is directed herewith that use of the following lubricants be discontinued in all fire-control equipment:

   Freezene medium refrigerating oil
   WS511 grease
   Univis 48 oil
   Gulf precision greases No. 1 and No. 2

--BuOrd M. F. Schoeffel.

MAINTENANCE ROUTINE

If all fire control equipment including connecting cables could be enclosed in a dehydrated chamber and protected against shock and vibration, perhaps daily checks would not be so important. Since the equipment is not enclosed, our next best bet is to OPERATE and TEST all equipment and instruments DAILY.

Most ships have check-off sheets for the purpose of recording the results of these daily tests. By keeping a record, a handy reference is afforded in the event of a failure. Of course, all ships have a fire control machinery history in which are kept records of all repairs and alterations, but this is too detailed to analyze quickly. Not only will you have a record of your daily tests as they run, but you will be the first one to know of a trouble. By keeping minor routine troubles eliminated through daily tests and maintenance procedures, you will find that major failures seldom occur. Your equipment will always be ready for any emergency or practice.

Summing up

1. Inspect all instruments periodically for moisture, dirt, oil, and grease. Clean them if any is present.
2. Lubricate according to applicable instructions.
3. Keep instruments that are exposed to weather properly covered, and watertight covers secured.
4. Operate daily all equipment in all possible combinations.
5. Keep a record (check-off sheet) of the daily tests.
6. Keep index cards on the instruments under your supervision and see that the instruments receive the required care.
7. Keep all spare parts in a clean, dry storeroom and make frequent checks on them so that they are always serviceable.

FIRE CONTROL TESTS AND CHECKS

Fire control tests apply to all the equipment on the ship for which the fire control division is responsible. So far, the discussion of tests has been very general in nature and rightly so because the idea was to show how vital tests are to proper maintenance. Now let's be more specific and enumerate the tests you will be required to know about.

1. Transmission tests (Daily).
2. Operational tests of equipment (Daily).
3. Dynamic accuracy tests (Periodically or when directed).
4. Alignment checks (When directed).

These are only a few of the tests that are run on fire control equipment. There are weekly, semimonthly, monthly, quarterly, and semiannual tests. These will vary according to the installation and it will be necessary for you to consult the applicable ordnance publications for detailed information when directed by the gunnery officer.

TRANSMISSION TESTS

Transmission tests are primarily for the purpose of checking the synchro transmission systems; however, much operating equipment other than the synchros are tested in the course of the tests.

Conducting a transmission test:

1. Establish telephone communication between all stations.
2. Man all stations; these include plotting rooms, turrets, mounts, guns, directors, and control stations.
3. Energize all circuits as you would for G. Q. primary control and place all guns and mounts in local control.
4. Transmit a synchro signal to every station possible and have the operators read back received quantities. This will include the battle order and the target designation system. Record each reading and the error, if any.
5. Direct all units that are controlled automatically to shift to ''automatic'' and report whether or not automatic operation is satisfactory, and the equipment is synchronized with the transmitted signal.
6. Repeat steps 4 and 5 for each director and each plotting room.

When the above procedure is completed, compare the results from the various stations and set-ups. If there are no discrepancies, the transmission test is complete and satisfactory. When some station reports the same error constantly, obviously the receiving station is at fault. If all stations report the same error, you should check the transmitting station in search for the trouble. During the course of the tests the variations in switching arrangement are such that you should be able to put your finger on the unit at fault with very little trouble. Merely look at the results of the transmission test and note under what conditions the error occurred.

DYNAMIC ACCURACY TEST

During the course of a transmission test you will find out whether the synchro followsups of the turret, mount, or the director power drives are in working order, and whether or not they will synchronize with the signal at given points. You cannot tell from these tests, however, how close they will follow the signal, so an additional test is used. This test is known as a DYNAMIC ACCURACY TEST, which means that the test is conducted with the equipment in motion.

Two special instruments are provided for dynamic accuracy tests; they are the DUMMY DIRECTOR and the ERROR RECORDER. The dummy director is the instrument which originates the signal to the turret, mount, or director power drive being checked, and the error recorder records the error (lag) on a strip of paper.

The dummy director transmits a ''rolling'' or sinusoidal synchro signal which may be varied in amplitude (degrees) and period (cycles per second). As you might guess, the dummy director has a set of synchro transmitters which are driven by a electro-mechanical sinusoidal generator.

The error recorder consists of a different synchro motor, a constant speed motor and drum, and a spark coil with a movable electrode attached to the rotor of the differential. The recorder receives two signals--one from the dummy director which is the signal being transmitted to the power drive under test and one from the unit under test which is the response of that unit.

Generally, the signal from the dummy director is sent over the transmission circuits from the plotting room, but it can also be hooked directly to the followup if desirable.

Now you know how a followup or power drive works. The followup receives a synchro signal and then nulls the signal by response. Of course, there's a lag between signal and response in all power drives, but it is very small when everything is working properly. It is the purpose of the dummy director and error recorder to measure this lag and, in turn, the dynamic accuracy. Here's how the test works:

The power drive is operated in automatic and receives the signal from the dummy director. The dummy director also transmits the same signal to the error recorder. The other signal to the error recorder comes from the response line of the power drive by synchro transmission; this signal represents the actual mount position at any instant. Then the error recorder continuously measures the DIFFERENCE between the signal and the mount position, and records it upon the strip of paper as it moves past the spark electrode on the differential rotor arm. The position of this electrode represents the difference between the two signals received by the differential. The spark from the electrode to the drum punctures the paper, making a permanent record of the error.

Each dummy director has with it a transparent scale graduated to elevate the error recorded on the paper strip. By placing the scale over the strip you can tell how much error exists for any given point in the test. Of course, if the maximum and average errors do not fall within the given specifications, the power drive must be adjusted or repaired as necessary.

Dynamic accuracy tests are run upon installation, after adjustments, overhaul, or repair and whenever the operation of the equipment makes such a test desirable.

REPAIR AND OVERHAUL OF FC INSTRUMENTS

Repair ships and tenders are equipped to undertake the routine overhaul and repair of fire control equipment carried by the various types of vessels which they service. Normally, Navy yards are only called upon to repair or overhaul fire control equipment during a ship's overhaul or in the event of major overhaul; these repairs are often made by the representatives of the manufacturer of the equipment. Major repair or overhaul should never be attempted by any other than fully qualified and authorized personnel from tenders, repair ships, Navy yards, or private concerns. Authority for major overhauls is obtained from the Bureau of Ordnance.

When you find through daily tests, routine inspections, or failures during use, that some instrument or piece of equipment is in need of repair, do your best to determine what is at fault and make a full report to your chief, the division officer, or directly to the gunnery officer, whoever is appropriate within the ship's organization. Authority must be obtained from the gunnery officer, and in turn the captain, before decommissioning any instrument for repairs. In the event the trouble is beyond own ship's force facilities, it will be necessary to call in repair technicians from a repair ship or base. In most cases these technicians will be able to locate, repair the defect, and make the required adjustments; you will be expected to assist in most cases. There are times, particularly on new types of equipment, when repair ships will not attempt or are not authorized to attempt repair and adjustment. Under these circumstances it is up to the gunnery officer to put through a work request to the ship's home Navy yard where experts or factory representatives will do the job.

PAINT FOR FIRE CONTROL INSTRUMENTS

The only paints recommended for fire control instruments are fire control gray and black enamels. The Bureau of Ordnance has conducted tests and found this to be the best for all types of conditions. Instruments exposed to the weather are the only ones that should ever require painting, and if they are kept properly protected during foul weather, they stand up remarkably well. Practically all fire control instrument cases are cast aluminum with a baked fire control enamel finish applied at the factory. This finish is very hard and glossy and the cast aluminum is especially corrosion resistant.

To sum up, paint instruments only when it is absolutely necessary. Painting a whole instrument because of a few scratches, chips, or worn spots may make it look better for a short time, but in the long run it will look worse. When it is necessary to paint, be sure the surface is scraped and wire-brushed clean; use only the recommended fire control enamels and be sure you have a good undercoating on the bare metal.

PACKING AND TRANSPORTING

When it becomes necessary to ship or transport an instrument, it must be packaged properly to prevent shock and exposure to the elements. If possible, the original shipping container should be used, since it will have the proper mountings to rigidly hold the instrument in place. Upon completion of packing, stencil the container HANDLE WITH CARE--DELICATE INSTRUMENT.

The gunnery officer and the chief will prepare the necessary shipping papers.

INSTALLATION

During the installation of fire control equipment the gunnery officer or his representative will inspect or supervise the work to see that it meets the specifications of the Bureau of Ordnance. Since you may be one of his assistants, you must also familiarize yourself with the necessary requirements. Many headaches can be avoided if the initial installation is correct and the proper inspections are made at the time of the installation. Don't hesitate to report any discrepancies you note to the gunnery officer or the chief.

SPARE PARTS FOR FIRE CONTROL EQUIPMENT

Spare parts are provided for all fire control instruments as follows: one set of vessel spares for every ship; one set of tender and one set of shore-base spares for each group of 8 destroyers, 4 cruisers, or 12 submarines; and one set of shore-base spare parts for each two battleships. Vessel spare parts are issued to ships in accordance with allowance lists and are usually delivered to the ship during initial fitting-out at the Navy yard.

Because replacement spares for fire control instruments are only available in limited quantities and are difficult to procure, it is important that you reduce the need for replacements to a minimum. This means close adherence to approved maintenance practices at all times.

Fire control storerooms must be dry and so arranged that spares are readily available for use, inspection, and inventory. Fire control storerooms are seldom constructed for that purpose, so it will be up to you to make use of your ingenuity and arrange them to your advantage.

A simple filing system for keeping track of spares is a timesaver and a convenience. Here's how it can be done:

1. Number each box or bin.
2. For each box or bin keep an indexed folder with the following information in it: (a) what equipment the parts are for, (b) the box or the number, (c) what spare

parts are in the box or bin, (d) what should be in it (this will be the allowance list), (e) where the missing spares were used, (f) what has been ordered, (g) what is to be ordered, and (h) the date that previously ordered parts are received. With a system like this, you will be able to tell in a few minutes whether you have a certain spare part, where it is, and if you don't have it, when it was ordered. Obviously, such an index would take the toil out of an inventory since you have at hand a continuous inventory.

OPTICAL INSTRUMENT CARE AND MAINTENANCE

Here again, as with other fire control instruments, you will find that optical instruments are delicate and precision-made. Replacements are available in very limited quantities, and therefore correct operation and proper maintenance are highly essential. Detailed descriptions and instructions as to the adjustment, care, and upkeep of optical instruments are contained in ordnance pamphlets, and will be supplemented from time to time by Bureau of Ordnance circular letters.

GENERAL RULES FOR OPERATION AND MAINTENANCE

1. All operating personnel must be thoroughly acquainted with detailed operational and maintenance instructions; these instructions must be carried out to the fullest extent that operating conditions permit.

2. All instruments, including those in store, should be inspected periodically. This should always be done when the services of an optical repair shop are available in order that the maximum benefit can be obtained.

3. Spare instruments are to be securely stored in a dry store room and maintained in a ready condition.

4. Repair or disassembly of optical equipment should never be attempted by other than qualified optical repairmen unless it is absolutely necessary. Correct reassembly of optical equipment can only be accomplished in repair shops where the necessary collimating equipment is available.

5. Take full advantage of optical repair facilities whenever they are available.

6. Surveyed instruments should be turned in to the nearest optical repair shop for salvage of usable material.

GAS AND DRY AIR IN OPTICS

One of the most frequent difficulties with optical equipment is the formation of moisture on the lenses; this particularly true when they are subject to rapid changes of temperature. The best protection against moisture is to see that the instruments are properly dried and gassed at regular intervals.

This is accomplished aboard ship either by opticalmen from a repair ship or by the ship's opticalmen and fire controlmen. Before gassing, air is passed from a cylinder under approximately 600 psi through a reducer and through the optical instrument (air at 600 psi is free of moisture), until the moisture can no longer be seen, or at least fifteen minutes if no moisture was visable in the first place. This drying process is followed by a flushing with some inert gas such as helium. Then the exhaust valve is closed and the instrument is filled with helium at a pressure of from 3 to 6 psi. For instruments not filled with gas, the drying process alone is carried out at periodic intervals or oftener if necessary to keep the instrument free of moisture.

It is sometimes possible to remove the protective glass on periscopes and lead computing sights and wipe the moisture off with lens paper. This method is advised against except in emergencies, and there is no time for some other method; then only an experienced man should attempt it.

CLEANING LENSES

When painting around optical equipment, caution should be exercised to keep paint off lenses and to wipe off paint specks immediately. In extreme cases alcohol may be used to clean lenses, but it should be used sparingly because alcohol is a solvent for cement. The best and most convenient thing to use is your own breath, followed by a brisk polishing with lense paper. For removal of smoke particles and dust, use a soft camel-hair brush; DO NOT use razor blades or sharp instruments to clean optics.

CAUTION: Do not expose optical equipment to the direct rays of the sun for any length of time. Such exposure may cause the balsam cement between the lenses to deteriorate.

To sum up general maintenance, Use OP's and OD's, paying particular attention to the sections on care and lubrication, tests, and adjustments. The information in this chapter shall in no way be taken to replace the vital information contained in Bureau of Ordnance publications, but rather to prepare you for their use. Remember, faithful routine maintenance is the lifeline of all fire control gear.

TOPIC 3

FIRE CONTROL CIRCUIT MAINTENANCE

A. You have learned:	References:
1. About fire control in general	
2. About a-c and d-c electricity	
3. About electrical machinery	
4. About electronics as applied to Power Drive Mk 4	
5. About hand tools you will use while in the Fire Control rate	
6. About safety precautions	
7. About Gun Fire Control System Mk 51	
B. You are learning:	
1. General maintenance	NavPers 10161-A, pages 214-215
2. Uses and care of meters and tools	NavPers 10164-A, pages 219-221 NavPers 92024, pages 2; 1 to 5
3. A review of electrical circuits	NavPers 10622-B, pages 376-377 NavPers 10164-A, pages 215-218, 221-224
4. A review of basic electronics	NavPers 10164-A, pages 224-229
5. About watertight boxes and fittings	NavPers 10164-A, pages 236-237
6. About electrical troubles	NavPers 10622-B, pages 33 to 40 NavPers 1064-A, pages 237 to 241
7. About cables and conductors	NavPers 10622-B, pages 40; 41; 378-380 NavPers 10164-A, pages 242-244; 283-292
8. A review of trouble-shooting	NavPers 10171, pages 195-217 NavPers 10164-A, pages 234-235

GENERAL MAINTENANCE

When first looking at almost any piece of fire control gear it may appear to be infinitely complex. In the case of some electrical circuits they may also seem to be completely beyond all understanding and physically jumbled up so as to appear carelessly thrown together. But such is not the case. To an experienced technician every small part is so arranged to form compact, orderly, and neatly assembled group of components. These go to make up separate pieces of gear. This fire control gear is easily understood by the technicians by the use of up-to-date drawings, test procedures, lubrication charts, and operating instructions in the form of OD's and OP's. These publications which are printed for every circuit and machine aboard ship, are for your benefit, so use them.

METERS AND TOOLS

1. ____________are used to determine resistance and must be used on a deenergized circuit only.
2. An ammeter is used to measure____________and is connected____________an energized circuit.
3. A voltmeter is used to measure____________and is connected across an energized circuit.
4. A megger is used to determine the____________of a circuit.
5. A special type meter that is used to measure more than one thing is called a/an____________.

As a Fire Control Technician you will use hand tools a great deal in your daily work. You will be expected to know how to use them--and use them right. The right tool can greatly speed up your work and at the same time make it easier, too. If you use the wrong tool it may result in injury to you, damage to the equipment you're working on, and to the tool you are using incorrectly.

Diagonal cutters are a handy and useful tool when correctly employed for such things as cutting wire, removing insulation, and cutting soft metal.

Needle-nose pliers are a light-duty tool and should be used for light work only, such as working with electrical wire.

While in the rate of Fire Control Technician you will be expected to perform many tasks involving soldering equipment. Most of the soldering jobs will be done by using electrical soldering guns and soldering irons. Remember that before a soldering job is started the soldering iron must be properly tinned. This "tin" on the soldering iron will last until the iron is overheated.

ELECTRICAL REVIEW

How much do you remember and understand about basic electricity and electronics? Following are some brief statements to be completed so that you can check for yourself how much you remember and understand concerning basic electricity and electronics.

1. ____________is the difference in potential between two points.
2. When one coulomb of electrons flow past a point in one second, one____________is said to flow.
3. ____________is the opposition to current flow and is measured in____________.
4. Electron flow is from____________to____________.
5. The basic relationship between voltage, current, and resistance is expressed by____________law.
6. In a series circuit the sum of the voltage drops equals the____________.
7. In a series circuit total resistance is the____________of the individual resistances.
8. In a parallel circuit total is the____________of the individual currents.

9. When inductance or capacitance is present in an a-c circuit, a ______________________ ______________ between voltage and current will result.

10. ______________ is total opposition to a-c current flow.

ELECTRONICS REVIEW

1. A ____ is used in the Power Drive Mk 4 as a power supply.

2. Filter circuits are used to smooth out __________________________.

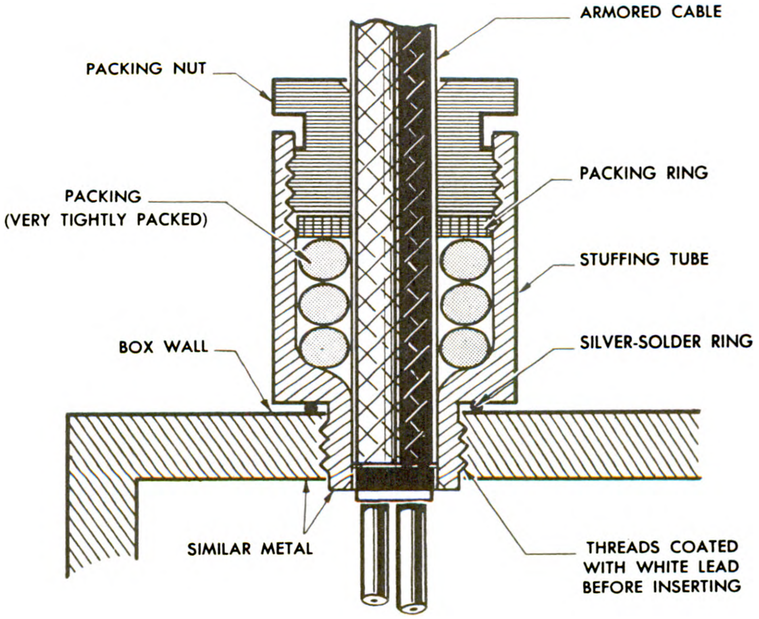
3. An ____________ tube is used to increase the size of a weak voltage.

4. Vacuum tubes are classed as to the number of ____________ they contain.

5. The output stage of the converter amplifier is a ____________ circuit.

WATERTIGHT BOXES AND FITTINGS

Aside from mechanical injury, the biggest source of electrical trouble on board ship is moisture. And salt-water moisture is the worst kind, because it is a conductor of electricity. Thus, when a cable or box becomes saturated with salt water two things happen: first, a current path to the ship hull is formed which is known as a ground, and second, especially where dissimilar metals are involved, electrolysis and corrosion occur and the connections or wire fittings are solwly eaten away. Therefore, practically all of the electrical wiring aboard ship is run in waterproof, fire-resistant, armored cables which terminate in watertight boxes.



WATERTIGHT STUFFING TUBE

The cables are run into boxes through stuffing tubes, also called terminal tubes. When renewing cable, these tubes must be repacked with a standard packing corresponding to the size of tube, and the packing ring and nut tightly secured. The preceeding diagram shows a cross-section of a stuffing tube properly assembled with an armored cable in place. Stuffing tubes similar to the one shown are used where cables pass through decks and bulkheads to insure watertight integrity. Where cables pass through deck, pipe risers are used in order to prevent mechanical injury to the cable. The stuffing tube is then inserted at the top of the pipe.

Terminal and junction boxes used for most fire control work are rated according to the number of terminals they contain, i.e., 10-wire box, or 50-wire box. All wires are lugged at the ends to insure solid connections at the terminal strips or blocks within each box. The lugs are often stamped with circuit designation numbers to assist the maintenance man in tracing out circuits. You'll find the cable leads laced together with cord and neatly arranged in each box to make for compactness and ruggedness. Always rearrange the box in this manner after pulling out leads for inspection, making tests, or relugging. Always make certain before leaving the box that the gasket of the box cover is in place and the cover is bolted down securely.

Summing up, whenever renewing wiring, every effort should be made to make solid connections, and watertightness at all boxes and cable fittings. Also, all wiring should be arranged to be as free from mechanical injury as possible. Always replace cable with the exact replacement or as specified by the gunnery officer.

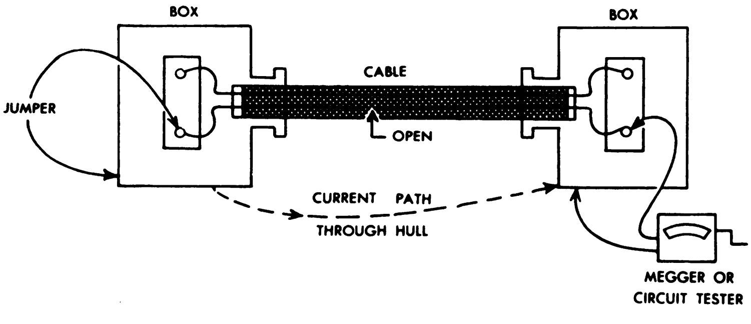
ELECTRICAL TROUBLE

It would be almost impossible to list all of the electrical troubles that might occur in electric wiring installations. However, as you know, most electrical trouble comes under the headings of shorts, opens, and grounds.

Shorts and grounds are closely related in that TWO GROUNDS--one on each side of the line--cause a short circuit. Ever partial grounds can give trouble as they may cause excessive current in the wires. In order to detect grounds before they become serious, DAILY GROUND TESTS are taken from the fire control switchboard with a megger. The megger, as you know, is a special ohmmeter for measuring insulation resistance. Some circuits have an intentional ground at the switchboard; this ground can be removed by means of opening a switch while taking ground tests.

It is a fairly easy task to find the location of a ground in a cable or circuit. The first step is to deenergize the circuit at the switchboard, get a megger, and go out to a box in the middle of the grounded cable. Then open the box, disconnect the grounded cable leads, and test each lead entering and leaving the box. Now halve the grounded section by going to another intermediate box, and repeat the tests. Finally, when you've located the bad section, perform a thorough test and inspection to definitely locate the exact location of the ground. Nine chances out of ten the ground will be caused by moisture. The tenth chance will disclose that the ground was caused by a mechanical injury or some defect.

An open circuit means the wire is broken or corroded in two, or a contact or fuse is defective. Broken wires in cagle twists at drectors, turrets, and guns are often a source of opens. Dirty contacts at slip rings and similar devices is another logical source of trouble.



TESTING FOR AN OPEN CIRCUIT

When you test a circuit for opens you test it for continuity. Once the fuses have been tested the next step is to test the circuit itself. This is done by going to a box located in the center of the circuit, disconnecting the leads of the cable entering and leaving the box, and testing with a circuit tester or megger. All tests are made with the circuit deenergized. After you've found out which leg of the circuit is open you go to another intermediate box and test in each direction as before.

CABLES AND CONDUCTORS

1. Cables are classified by the ____________ of conductors, use of the cable, and ____.
2. Conductors are __________________________ and are designated by a system of letters and numbers.

TROUBLE-SHOOTING

Trouble-shooting is actually two jobs--locating and fixing. Once you've found the trouble, you ought to have no trouble in fixing it. But finding it takes a combination of know-how, curiousity, and instinct.

First of all, you must know how your equipment is supposed to work--and in all phases of its operation. Then by referring to the OP you can usually localize the trouble to a specific unit.

By recommended testing techniques you can localize the trouble to the faulty part. Next, repair or replace the part and finally retest the system for correct operation.

MASTER MATERIAL LIST

Course: Experimental--Teaching Basic Electricity and Electronics with the MK 51 GFCS and the MK 4 Power Drive as the primary vehicle.

Date Curiculum was prepared: ____________________

Class size: 30

A. Texts

Item No.	Navy No.	Description	Per Man	Per Inst	Per Cl
1.	NavPers 10064	Study Guide for F. C. 3. Prepared by the Bureau Personnel	1	1	40
2.	NavPers 10163A	Fire Controlmen 3 Vol. 1 Navy Training course prepared by the Bureau of Naval Personnel. Date of publication 1951.	1	1	40
3.	NavPers 10164A	Fire Controlmen 3 Vol. 2 Navy Training course prepared by the Bureau of Naval Personnel. Date of publication 1952.	1	1	40
4.	NavPers 10170	Electricity for Fire Controlmen and Fire Control Technicians Vol. 1 Navy Training course. Prepared by the Bureau of Naval Personnel. Date of publication 1951.	1	1	40
5.	NavPers 10171	Electricity for Fire Controlmen and Fire Control Technicians Vol. 2 Navy Training course. Prepared by the Bureau of Naval Personnel. Date of publication 1951.	1	1	40
6.	NavPers 10622B	Electricity. Basic Navy Training course. Prepared by the Bureau of Naval Personnel. Date of publication 1951.	1	1	40
7.	NavPers 14005	Telephone Talkers Manual. Prepared by the Headquarters of the Commander-in-Chief, Navy Department Washington D. C. Date of publication November 19, 1943.	1	1	40
8.	OP 821A	Train Power Drive MK 4, Elevation Power Drive MK 4, 40 MM Mount Mark 1 Mod 2 and 1.1 Mount Mark 2 Mod 6. A Bureau of Ordnance Publication. Date of publication 18 October 1944.	1	1	40
9.	OP 1040	Gun Sight MK 14 Mods 6, 7, 8, 12, 13, 14 and 15. Prepared by the Bureau of Ordnance. Date of publication 4 March 1946.	1	1	40
10.	OD 4424	Gun Director Mark 51, Mod 2 Operators Manual. Prepared by the Sperry Byroscope Company Inc., Brooklyn, N. Y. Date of publication December 22, 1942.	1	1	40
11.	OD 4429	Gun Sight Mark 14 Mod 2, 3 and 4. Operators Manual. Prepared by the Bureau of Ordnance. Date of publication May 1943.	1	1	40

B. References

Item No.	Navy No.	Description	Per Man	Per Inst	Per Cl
1.	NavPers 10052B	Training Courses and Publications		1	3
2.	NavPers 10077	Blueprint Reading, prepared by Chief of Naval Air Technical Training and Bureau of Naval Personnel. Date of publication 1951.		1	3
3.	NavPers 10085	Basic Hand Tool Skills. Prepared by the Bureau of Naval Personnel. Date of publication 1954.		1	3
4.	NavPers 10623A	Use of tools. Basic training course. Prepared by the Bureau of Naval Personnel. Date of publication 1952.		1	3
5.	NavPers 16103B	Manual for Navy Instructors. Prepared by the Bureau of Naval Personnel. Date of publication April 1, 1949.		1	3
6.	NavPers 16115	Supplement to telephone talkers manual NavPers 14004.		1	3
7.	NavPers 16116B	Naval Ordnance and Gunnery. Prepared by the Department of Ordnance and Gunnery. Edited and produced by the Bureau of Naval Personnel. Date of publication September 1950.		1	3
8.	NavPers 16808A	Constructing and Using Achievement Test. Prepared by the Bureau of Naval Personnel. Date of publication January 1949.		1	3
9.	NavPers 18068	Manual of Qualifications for advancement in rate. Prepared by the Bureau of Naval Personnel. Publication date September 1952.		1	3
10.	NavPers 91882	Basic Electronics Vol. 1. Electricity and Electronics Training Series. Prepared by the Bureau of Naval Personnel. Date of publication 1952.		1	3
11.	NavPers 91883	Basic Electronics Vol. 2. Electricity and Electronics Training Series. Prepared by the Bureau of Naval Personnel. Date of publication 1952.		1	3
12.	NavPers 92021	Basic Electricity Vol. 2. Electricity and Electronics Training Series. Prepared by the Bureau of Naval Personnel. Date of publication 1954.		1	3
13.	NavPers 92022	Basic Electricity Vol. 2. Electricity and Electronics Training Series. Prepared by the Bureau of Naval Personnel. Date of publication 1954.		1	3
14.	NavPers 92023	Basic Electricity Vol. 3. Electricity and Electronics Training Series. Prepared by the Bureau of Naval Personnel. Date of publication 1954.		1	3
15.	NavPers 92024	Basic Electronics Vol. 4. Electricity and Electronics Training Series. Prepared by the Bureau of Naval Personnel. Date of publication 1954.		1	3
16.	OP 1140	Basic Fire Control Mechanisms. Prepared by the Ford Instrument Company, Inc., Long Island City, N. Y.. Date of publication September 1944.		1	3
17.	OP 1303	United States Navy Synchros. Prepared by the Bureau of Ordnance and the Bureau of Ships. Date of publication 15 December 1944.		1	3
18.	OP 1752	Gun Sight Mark 14, Overhaul Manual, Prepared by Bureau of Ordnance. Date of publication when available__________________.		1	3

Item No.	Navy No.	Description	Per Man	Per Inst	Per Cl
19.	OP 1887	Ship board Gunnery; Logs and Records. Prepared by the Bureau of Ordnance. Date of publication 28 July 1952.		1	3
20.	OD 2298	Gun Sight Mark 14, Caging Device.		1	3
21.	N.S. 250-660-42	Electric Shock. Its Causes and Prevention. Prepared by the Bureau of Ships. Publication date 1 October 1954.		1	3
22.	OP NAV 34 F1	United States Navy Safety Precautions. Prepared in the office of the Chief of Naval Operations with the collaboration of the technical assistants in the various bureaus and offices of the Department of the Navy.		1	3
23.		RCA Receiving Tube Manual. Prepared by Radio Corporation of America, Harrison, N. J., current edition.		1	3
24.	Tra Pac 101	Alignment of Ordnance Installations. Prepared by Commander Training Command, Pacific Fleet. Date of publication 10-54.		1	3

C. Equipment

Item No.	Description	Per Cl
1.	Gun Director MK 51 Mod 2 (other modification may be used but will require adaptation) SS N-Z950-SK-104522-2. Source: Ordnance Supply System.	10
2.	Gun Sight MK 14 Mod 8 (10 installed in operating condition, 1 non operating for classroom use) SSN-Z 958-SK-104536-1. Source: Ordnance Supply System.	11
3.	Unit, Air Supply for Gun Sight MK 14 Mod 8--SSN-Z 958-SK-104521. Source: Ordnance Supply System.	10
4.	Hose Assembly for Air Supply Unit SSN-Z-958-325559-1. Source: Ordnance Supply System.	20
5.	Cable Assembly for Gun Sight MK 14 Mod 8 SSN-Z-958-32559-2. Source: Ordnance Supply System.	10
6.	Check Gauge for Gun Sight MK 14 Mod 8 SSN-Z-958-325849-1. Source: Ordnance Supply System.	10
7.	Power Drive MK 4. Sets of train and elevation (these equipments may be installed on Gun Mounts 40 MM MK 1 Mod 2 or on test stands whichever is feasible). Source: Ordnance Supply System.	10
8.	Gun Mount 40 MM MK 1 Mod 2 (desireable but not necessary). Source: Ordnance Supply System.	2
9.	Power Drive MK 4. Set at train and elevation complete assembly--non operating for classroom use. Source: Ordnance Supply System.	1
10.	Calibration and Training Fixture--MK 1 for use on Gun Sight MK 14 Mod 8--SSN-Z-958-SK-104540. Source: Ordnance Supply System.	10
11.	Motion Picture Projector 16 MM type AQ-2 (1) BuShips Stock #S18-PO24707-7 or similar. Source: District Training Aids.	1
12.	Screen, projection spring roller mounted with tripod--picture size 50" x 67" SSN-GA18-S-1561-820.	1
13.	Projector 35 MM Strip Film type-IC/QPI-2VL BuShips Stock #S18-P-24708-700 or similar. Source: District Training Aids.	1
14.	Sound Powered Telephones. Headset-chestset type SSN-G17-T-3055-20 or similar. Source: Ordnance Supply System.	30
15.	Jack Box Telephone type. SSN-A17-B-31950 or similar. Source: Supply System.	30
16.	Multimeter AN/PSM-4 SSN F 16-Q-172840-200. Source: Electronic Supply System (for instructor use).	2
17.	Volt-Ohm-Milliammeter Navy type--OIS-60039. SSN-F17-Q-741160-200 Source: Electronic Supply System. (for student use).	14
18.	Watch, stop, Spec. Fed. GG-W-111, type B, continuous running, SSN-GC18-W-160, 15 jewels. Source: Supply System.	11
19.	Complete tram assembly, SSN-Z019-8-Z-935 consisting of: Tram and test gauge box, Z019-8-Z-1215-900 Tram assembly Z019-8-Z-934-900 Tram test guage assembly Z019-8-Z-939-900 Source: Ordnance Supply System.	1
20.	Boresight MK 2 (non-optical) SSN Z026-SK-140500. Source: Ordnance Supply System.	1
21.	Projector, Visual Aid (Overhead) Device 1-BC-3 500W, 115 VAC--District Training Aids.	1

D. Films

The source of all film is the cognizant district training aids office. Listed in "Catalog of Training Films." NAVPERS 230058.

Item No.	Navy No.	Title	Running Time	Per Cl
1.	MC 712	Electro-Dynamics	11 Minutes	1
2.	MC 777	The Story of a Storage Battery	10 Minutes	1
3.	ME 1051H	Machine Shop Work-Bench Work-Fundamentals of Filing	10 Minutes	1
4.	MN 1540A	Capacitance	30 Minutes	1
5.	MN 1540B	Inductance	36 Minutes	1
6.	MN 1540C	RCL	35 Minutes	1
7.	MN 1540U	Amperes, Volts and Ohms	8 Minutes	1
8.	MN 1540V	Series and Parallel Circuits	7 Minutes	1
9.	MN 1540W	Synchro Systems Part I	17 Minutes	1
10.	MN 1540X	Synchro Systems Part II	13 Minutes	1
11.	MN 1549	LCGS MK 14	17 Minutes	1
12.	MA 1929A	Care and Use of Hand Tools--Wrenches	20 Minutes	1
13.	MA 1929D	Care and Use of Hand Tools--Hammers	10 Minutes	1
14.	MA 1929E	Care and Use of Hand Tools--Punches--Drifts--Bars	14 Minutes	1
15.	MA 1929F	Care and Use of Hand Tools--Hacksaws	18 Minutes	1
16.	MN 2031A	Vacuum Tubes	16 Minutes	1
17.	MN 2031B	The Triode and Multi-Purpose Tubes	14 Minutes	1
18.	MA 2333A	Electricity and Magnetism Part I	13 Minutes	1
19.	MA 2333B	Electricity and Magnetism Part II	20 Minutes	1
20.	MC 3305	What is Electricity	20 Minutes	1
21.	MN 3711A	Battle Telephone Talkers	17 Minutes	1
22.	MN 3485B	Electricity Safety Precautions		1
23.	ME 6028	Electrical Work--Electrical Machines--Rotating Magnetic Fields.	10 Minutes	1
24.	ME 6092E	The Triode Amplifier	13 Minutes	1
25.	MN 7831A	Care and Use of Hand Tools--Part I An Introduction to Hand Tools	20 Minutes	1
26.	MN 7831B	Care and Use of Hand Tools--Part II Basic Layout Tools	15 Minutes	1
27.	MN 7831C	Care and Use of Hand Tools--Part III Hacksaw	10 Minutes	1
28.	MN 7831D	Care and Use of Hand Tools--Part IV Files and Filing.	10 Minutes	1
29.	MN 7831E	Care and Use of Hand Tools--Part V Twist Drills	15 Minutes	1
30.	MN 7831F	Care and Use of Hand Tools--Part VI Metal Cutting Chisels	10 Minutes	1
31.	MN 7831G	Care and Use of Hand Tools--Part VII Threading Taps and Dies	30 Minutes	1
32.	MN 7831I	The Use of Soldering Coppers	15 Minutes	1

D. Strip Films

Item No.	Navy No.	Title	Running Time	Per Cl
1.	SN 228A	Static Electricity Part I		1
2.	SN 229C	Current Electricity Part III		1
3.	SN 1449A	Electrical Control Part I		1
4.	SN 1449B	Electrical Control Part II		1
5.	SN 1449C	Electrical Control Part III		1
6.	SN 1727A	G.S. MK 14 Theory and General Description	24 Minutes	1
7.	SN 1727B	G.S. MK 14 Action of Gyro Units (Train)	19 Minutes	1
8.	SN 1727C	G.S. MK 14 Action of Gyro Units (Elevation)	23 Minutes	1
9.	SN 1727D	G.S. MK 14 Mechanical Construction (Sight Unit)	24 Minutes	1
10.	SN 1727E	G.S. MK 14 Mechanical Operation (Power Unit)	13 Minutes	1
11.	SN 1727G	G.S. MK 14 Maintenance	30 Minutes	1
12.	SA 2519A	Vacuum Tubes Part I Fundamentals		1
13.	SA 2519B	Vacuum Tubes Part II Rating and Testing		1
14.	SA 2519C	Vacuum Tubes Part III Amplifier Fundamentals		1
15.	SAN 3485G	Electrical Power Afloat Electrical Cables and Fittings		1
16.	SC 6655	Electric Motors		1

E. Graphics

Source of charts is the cognizant district training aids office. Reference source is Training Aids Catalog-NAVPERS-230056 except as noted.

Chart No.	Description	Per Cl
1.	Methods of Biasing--Battery Bias	2
3.	Power Supply Bleeder	2
4.	Choke in Negative Lead, Power Supply	2
5.	Method of Biasing--Grid Leak	2
6.	Method of Biasing--Cathode Resister	2
7.	Obtaining Screen and Plate Potentials	2
8.	Pentode RC coupled circuit	2
9.	Wheel Diagram Method of Drawing a Sine Wave	2
10.	Bias for Class "A" Operation	2
11.	Bias for Class "B" Operation	2
12.	Bias for Class "C" Operation	2
13.	Method of Obtaining Excitation Voltage--I R Drop	2
14.	Method of Obtaining Excitation Voltage--IXC Drop	2
15.	Method of Obtaining Excitation Voltage--IXL Drop	2
16.	Method of Obtaining Excitation Voltage--Mutual Induction	2
18.	Push-Pull Amplifier	2
20.	Phase Relations in a Series Circuit	2
51.	6L6 Vacuum Tube	2
55.	How a Simple Rectifier Works	2
60.	Circuit Nomenclature	2
65.	Radio Standard Symbols and Color Code	2
66.	Influence on Electron Flow by Anode Potential	2
68.	Identification of Navy Cables and Conductors	2
69.	Identification of Navy Cables and Conductors	2
71.	Power Supply Showing Choke Input Filter System	2
74.	Meter Circuits	2
79.	Sine Wave Characteristics	2
81.	Superinposing A.C. on D.C.	2
85.	Factors Covering Energy Transfer Between Coils	2
87.	Factors Covering Capacitors	2
94.	Electro-Magnetism Based on Electron Flow	2
95.	Repelling and Attracting Magnetic Fields	2
96.	Attraction and Repulsion of Electro-Magnetic Fields (Straight Conductor)	2
97.	Attraction and Repulsion of Electro-Magnetic Fields (Loop Conductor)	2
104.	Factor Covering Generation of EMF (A)	2
105.	Factor Covering Generation of EMF (B)	2

NAVPERS NO.

70229	MK 14 G.S. Schematic Drawing	4
17501M	Pictorial Manual of Radio Material Charts (Size 35" x 45")	2
22-B-1-i	Hand Tools Chart (Reference (b), NAVEXOS P-530-1, Special Devices Guide)	1

NAVORD CHART

F1-44	(4 sheets) Gunsight MK 14, Mod 6,7,8.	4

Locally prepared Charts

Flip Chart or Transparency No.	Description	Per Cl
II-2-1	Atom and Molecule	1
II-2-2	Current Flow	1
II-2-3	Current Flow	1
II-3-1	Electrical Schematic Symbols	1
II-3-2	Primary Cell	1
II-3-3	Primary Cell	1
II-3-4	Storage Battery	1
II-4-1	Metric Relationships	1
II-5-1	Potential Difference	1
II-5-2	Electrical Charges	1
II-6-1	Resistance Factors	1
III-2-1	Series Circuit	1
III-2-2	Parallel Circuit	1
III-2-3	Series--Parallel	1
III-2-4	Open Circuit	1
III-2-5	Short Circuit	1
III-2-6	Grounded Circuit	1
III-3-1	Series Connection	1
III-3-2	I, E and R in Series	1
III-6-1	Parallel Circuit	1
III-8-1	Series--Parallel Connections	1
III-8-2	Series--Parallel Circuits	1
III-8-3	Straight-Lining	1
III-9-1	Kirchoff's First Law	1
III-9-2	Unknown Current	1
III-9-3	Kirchoff's First Law	1
III-9-4	Kirchoff's Second Law	1
III-9-5	Kirchoff's Second Law	1
III-9-6	Kirchoff's Law	1
IV-1-1	Waveforms	1
IV-1-2	Generating A.C.	1
IV-1-3	Sine Wave	1
IV-1-4	Voltage and Current	1
IV-2-1	Voltage and Current Resistive A.C. Current	1
IV-2-2	Resistive Power	1
IV-3-1	Magnetic Fields	1
IV-3-2	Flux Field	1
IV-3-3	Flux Field	1
IV-3-4	Phase Relationship	1
IV-3-5	Inductance Factors	1
IV-3-6	Pure Inductive Circuit	1
IV-3-7	Mutual Induction	1
IV-3-8	Factors Affecting Inductive Reactance	1
IV-3-9	Pure Inductive Power	1
IV-3-10	Inductive and Resistive Power	1
IV-4-1	Capitance	1
IV-4-2	Charge of a Capacitors Plate	1
IV-4-3	Capacitor Action	1
IV-4-4	Capacitor Action	1
IV-4-5	D. C. Current Flow	1
IV-4-6	C. C. Current Flow	1
IV-5-1	The Capacitor	1
IV-5-2	Factors Affecting Capacitance	1
IV-5-3	Capitance Reactance	1

MASTER MATERIAL LIST

Flip Chart or Transparency No.	Description	Per Cl
IV-5-4	How C Affects Xc	1
IV-5-5	"E and I Relationship"	1
IV-5-6	Capacitive and Resistive Power	1
IV-6-1	Vector Representation of a Series Circuit	1
IV-6-2	RL Series Circuit	1
IV-6-3	RC Circuits	1
IV-6-4	Xl and Xc Circuits	1
IV-6-5	Solving and RCL AC Circuit	1
VI-1-1	A. C. Generator	1
VI-1-2	D. C. Generator	1
VI-2-1	Series Generator	1
VI-2-2	Shunt Generator	1
VI-2-3	Compound Generator	1
VI-2-4	Commutation	1
VI-2-5	Interpoles	1
VI-2-6	Flux Distortion	1
VI-2-7	Compensating Windings	1
VI-3-1	One Loop Motor Action	1
VI-3-2	Breakdown of a Conductor	1
VI-4-1	EM F of Self Induction	1
VI-4-2	Mutual Induction	1
VI-4-3	XFMR Losses are Small	1
VI-4-4	High CEMF--No Load	1
VI-4-5	Turns and Volts	1
VI-4-6	Core and Winding Design	1
VI-5-1	Split Phase Induction Motors	1
VI-7-1	Cable Construction	1
VI-7-2	Circuit Checking	1
VI-8-1	Voltmeter Connections	1
VI-8-2	Ohmmeters	1
VI-8-3	The Megger	1
VI-8-4	Moving-Vane Meter	1
VI-8-5	Ammeters	1
VI-8-6	Electrodynamometer	1
VI-8-7	Meter Movement	1
VI-8-8	Rectifiers	1
VI-8-9	Ammeter Movement	1
VI-8-10	Reading Meters	1
VI-9-1	Synchro Action	1
VI-9-2	Synchro Action at $60^\circ + 90^\circ$	1
VI-9-3	Synchro Voltages	1
VI-9-4	Synchro Action	1
VI-9-5	Synchro Action	1
VI-9-6	C. T. Schematics	1
VI-9-7	C. T. Action--Zero Signal	1
VI-9-8	C. T. Action	1
VI-9-9	C. T. Response	1
VI-9-10	C. T. Follow-up	1
VI-9-11	Electrical Lock Method	1
VI-9-12	Standard Motor Method	1
VI-9-13	Voltmeter Method	1
VI-9-14	Voltmeter Method	1
VII-7-1	Triode Amplification	1
VII-7-2	Amplification Factor	1
VII-7-3	Plate Resistance	1
VII-7-4	Transconductance	1

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Flip Chart or Transparency No.	Description	Per Cl
VIII-3-1	Fabricated Work	1
IX-1-1	Mark IV Power Drive	1
IX-1-2	D. C. Generator	1
IX-1-3	Shorted Quadrature Brushes	1
IX-1-4	Armature Reaction	1
IX-1-5	Compensating Windings	1
IX-1-6	Amplidyne Operational Diagram	1
IX-1-7	Amplidyne Schematic	1
IX-4-1	Sound-Powered Telephone	1
IX-4-2	Headset Wiring Diagram	1
IX-4-3	Sound-Powered Telephone Circuits	1
X-1-1	Roller Path Inclination	1

F. Mockups, Models and Trainers

Item No.	Description	Per Cl
1.	29-T-1 Vacuum Tube Mockup	2
2.	NavPers 17205 Crow rotating electrical machine--D.C. machine kit (basic kit) and A.C. machine kit (supplementary to D. C. machine kit) from Universal Scientific Co. Inc., Vincennes, Indiana	2
3.	;;D.C.milliameter, panel mounted, model 602, metal rod, 4 inch scale 3-11/16 inch flange, 3 inch body 1 1/4 inch body depth, "zero-center", one-zero-one milliamp scale. Manufacturer--Hoyt Electrical Instrument Works, Penacook, New Hampshire.	5
4.	Transformer Demonstration Panel--Mfg locally	1
5.	Circuit Demonstration Panel--Mfg locally	1
6.	Converter Amplifier Demonstration Panel--Mfg locally	1
7.	Polyphase Demonstration Board--Mfg locally	1
8.	Fire Control Problem Mock-Up--Mfg locally	1
9.	Instruction Model--Rate Gyro Unit, Gun Sight Mark 14, Sperry Part No. 656631, Sperry Gyroscope Co., Inc., Brooklyn, N. Y.	1

;; Indicates to be ordered from Radio Masters 19th Edition

G. Hand Tools

I. GENERAL PURPOSE

Item No.		Description	SSN	Price	Per Cl
	A.	SCREW DRIVERS (COMMON)			
1.		1. 1-1/2" plastic	G41-S-1083-5	.18	@12
2.		2. 4" "	G41-S-1102-5	.18	@12
3.		3. 6" "	G41-S-1104-5	.22	@12
4.		4. 8" "	G41-S-1106-5	.36	@12
5.		5. 12" "	G41-S-1110-5	.54	@12
	B.	HAMMERS BALL PEEN			
6.		1. 1/4 lb. machinist	G41-H-520	.43	@ 2
7.		2. 1/4 lb. machinist	G41-H-521	.46	@ 2
	C.	HAMMER SOFT FACED			
8.		1. Brass 1/4 lb.	G41-H-167-940	.75	@ 2
9.		2. Plastic 1/2 lb.	G41-H-485-125	.68	@ 2
	D.	MALLETS			
10.		1. Rawhide	G41-M-478	.70	@ 1
	E.	SCREW DRIVERS PHILLIPS			
11.		1. 3"	G41-S-1636-5	.12	@ 6
12.		2. 6"	G41-S-1640-5	.32	@ 6
13.		3. 8"	G41-S-1642-5	.48	@ 6
	F.	SCREW DRIVERS JEWELERS			
14.		1. Set .025 to .1 tip	G41-S-1325	1.50	SE 2
	G.	SCREW DRIVERS OFFSET			
15.		1. Double end 3"	G41-S-1393-75	.15	@ 6
16.		2. Double end 6"	G41-S-1399	.24	@ 6
17.		3. Double end 4"	G41-S-1397	.16	@ 6
	H.	PLIERS			
18.		1. Slip-Joint	G41-P-1631	.30	@ 6
19.		2. Long Nose	G41-P-1899-800	.88	@ 6
20.		3. Round Jaw	G41-P-1914	1.10	@ 6
21.		4. Side Cutting	G41-P-1974	.85	@ 6
22.		5. Plier Wrenches	G41-W-458	.85	@ 2
23.		6. Diagonal Cutters	G41-P-1714	.83	@ 6
	I.	EXTRACTOR SCREW AND BOLT			
24.		1. Size # 1	G41-E-565	.16	@ 1
25.		2. Size # 2	G41-E-566	.16	@ 1
26.		3. Size # 3	G41-E-567	.19	@ 1
27.		4. Size # 4	G41-E-568	.22	@ 1
	J.	NIPPERS			
28.		1. Integral 6"	G41-N-554	.93	@ 1
	K.	PUNCHES AND DRIFTS			
29.		1. Center	G41-P-3181-50	.08	@ 6
30.		2. Drive	G41-P-3602	.08	@ 6
31.		3. Drift	G41-P-600	.15	@ 2
32.		4. Leather Gasket	G41-P-3411	.22	@22
	L.	VISE			
33.		1. Machinist	G41-V-272	11.60	@ 1

II. WRENCHES

Item No.		Description	SSN	Price	Per Cl
	A.	OPEN FIXED			
34.		1. Light duty, thin head	GM5120-228-9527	.24	@ 6
35.		2. " " " "	G41-W-1176-8	.24	@ 6
36.		3. " " " "	G41-W-1176-12	.25	@ 6

Item No.	Description	SSN	Price	Per Cl
37.	4. Light duty, thin head	G41-W-1176-18	.26	@ 6
38.	5. " " " "	G41-W-1176-33	.36	@ 6
B.	OPEN ADJUSTABLE			
39.	1. Normal duty 6"	G41-W-485	.49	@ 2
40.	2. Normal duty 10"	G41-W-487	.75	@ 2
C.	PIPE STILLSON			
41.	1. Pipe Stillson	G41-W-1651	.35	@ 1
D.	BOX END			
42.	1.	G41-W-619-612	.21	@ 6
43.	2.	G41-W-619-618	.25	@ 6
44.	3.	G41-W-619-630	.50	@ 6
45.	4.	G41-W-619-660	.98	@ 6
E.	SOCKET			
46.	1. a. Spin type 3/16			2
	b. 1/4			2
	c. 5/16			2
	d. 11/32			2
	e. 3/8			2
	f. 7/16			2
	g. 1/2			2
47.	2. Detachable socket	G41-W-2997	12.30	SE 1
F.	HEX KEY ALLEN			
48.	1. Double end .035	G41-W-2443	.01	@10
49.	2. " " 5/64	G41-W-2446-2	.016	@10
50.	3. " " 1/8	G41-W-2450-2	.02	@10
51.	4. " " 1/4	G41-W-2454-2	.05	@10
G.	SPANNER			
52.	1. Adjustable Hock	G41-W-3249-900	.80	@1
53.	2. Fixed faced	G41-W-3247-735	1.00	@ 1
H.	DIAL ADJUSTMENT	(Pc #163301)		
		Z01Z-16 3301-90	9.00	@ 6
III.	CUTTING TOOL-METAL			
A.	SNIPS TINNERS			
54.	1. Hand--straight cut	041-S-2813	1.00	@ 1
B.	HACKSAWS			
55.	1. Hacksaw frame--adj	041-4-3394	.77	@ 1
	2. Hacksaw blades			
56.	a. 18T	041-B-1168-20	.11	@10
57.	b. 32T	041-B-1174-49	.13	@10
C.	CHISELS			
58.	1. Cape	G41-C-1050	.24	@ 1
59.	2. Cold	G41-C-1108	.54	@ 1
60.	3. Sidecutting	G41-C-1270	.54	@ 1
D.	FILES			
61.	1. Needle set	G41-F-2700	2.20	SE 1
	2. Single cut			
62.	a. Mill--Bastard	G41-F-1155	.23	@ 2
63.	b. Mill--Second	G41-F-1168	.10	@ 2
64.	c. Mill--Smooth	G41-F-1181	.27	@ 2
65.	d. Round--Second	G41-F-1315	.18	@ 2
66.	3. Taper--Slim	G41-1501	.15	@ 2
	3. Double cut			
67.	a. Warding	G41-F-1606	.24	@ 2
68.	b. Square	G41-F-1374	.25	@ 2

Item No.		Description	SSN	Price	Per Cl
69.		c. Half Round	G41-F-941	.42	@ 2
70.		d. Knife	G41-F-1111	.46	@ 2
71.	E.	Brush-File Cleaner	G38-C-400	.69	@ 2
	F.	DRILL-TWIST			
72.		1. Wire Gauge Size #1-#60	G40-D-1889	8.10	SE 1
73.		2. Fractional Size	G40-D-1677-75	2.90	SE 1
74.		3. Stand	G40-S-2854	1.85	@ 1
75.	G.	Counter Sink	G40-C-1190	.70	@ 1
76.	H.	Drills--Power Electric	G40-D-339-5	26.50	@ 1
77.	I.	Drills--Hand	G41-D-1828	3.60	@ 1
78.	J.	Reamers	G41-R-2050	16.90	SE 1
79.	K.	Threading Sets--Standard Screw Plate	G41-T-1848	9.80	SE 1
IV.	GAGES AND INDICATORS				
	A.	GAGES			
80.		1. Screw Pitch	G41-G-270	2.80	@ 1
81.		2. Wire Gage	G41-G-530	3.00	@ 1
82.		3. Thickness Gage	G41-G-410	.92	@ 1
83.		4. Twist Drill	G41-G-460	2.00	@ 1
	B.	INDICATORS--SPECIAL TOOLS			
84.		1. Rule--Machinist	G41-R-2992	1.00	@ 2
85.		2. Scribe	G41-S-2030	.29	@ 2
86.		3. Calipers Inside	G41-C-344	1.80	@ 1
87.		4. Calipers Outside	G41-C-354	1.80	@ 1
88.		5. Dividers	G41-D-1367	1.20	@ 1
89.		6. Caliper-Micrometer	G41-C-220	6.00	@ 1
90.		7. Dial Test Indicator	G41-I-100	20.50	@ 1
91.		8. Finger--Mechancial	G41-T-3215-967	.42	@ 2
V.	SOLDERING				
	A.	SOLDERING IRONS AND GUNS			
92.		1. Standard 85W	G41-I-695	1.30	@ 1
93.		2. Standard 350W	G41-I-685	3.10	@ 1
94.		3. Pencil 25W	G41-I-685-100	1.85	@ 6
95.		4. Gun--Weller	G41-G-1865-450	6.50	@ 2
96.		5. Temperature Regulators			
97.		6. Solder--Rosin Core 1/16"	G46-S-915-3	.75	lb 5
VI.	METAL FASTENERS				
	A.	MACHINE SCREWS			
98.		1. Flathead	GM43-S-8009	.41	GR 1
99.		2. Round	GM43-S-9054	.60	GR 1
100.		3. Oval	GM43-S-8598	.88	GR 1
101.		4. Fillister	GT43-S-11618	.52	GR 1
	B.	MACHINE SCREWS--SPECIAL			
102.		1. Binding Head	AC43-S-58530-2300	.02	@ 6
103.		2. Crossed-Recrossed Flat	GT43-S-7735-306	.75	GR 1
104.		3. Crossed-Recrossed Round	GT43-S-8770-482	.97	GR 1
105.		4. " " Oval	GT43-S-8454-20	.37	
106.		5. " " Fillister	GT43-S-7174-695	2.60	GR 1
	C.	SET SCREWS			
107.		1. Square Head	GM43-S-17800	.025	@ 6

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Item No.	Description	SSN	Price	Per Cl
108.	2. Socket Head--Cup	GM43-S-17348-610	.025	@ 6
109.	3. " " Cone	GM43-S-17318-640	.035	@ 6
110.	4. " " Half-Dog	GM43-S-17675-9750	.035	@ 6
111.	5. Headless Cup	GM43-S-16672	.007	@ 6
D.	BOLTS			
112.	1. Eye	G43-B-13658	.33	@ 3
113.	2. Stripper	G43-B-24210-215	.14	@ 3
114.	3. Stud	G43-B-24360-60	.05	@ 3
115.	4. Machine Hex 3/8" x 16T x 1/4"	G43-B-75011-7400	.15	@ 3
E.	PINS			
116.	1. Cotter 3/32 x 1	G42-P-6488	.12	Bx 1
117.	2. Straight Headless	G42-P-11720	.005	@ 6
118.	3. Dowel 3/16" x 1/2"	G42-P-7420-820	.04	@ 6
119.	4. Tapered Plain 0.109 L.E. 3/4" #4/0	G42-P-12928	1.00	Bx 1
F.	KEYS			
120.	1. Machine	G42-K-3039-315	.035	@ 6
121.	2. Woodruff	G42-K-4229-1130	.004	@ 6

H. Supplies

Item No.	Description	SSN		Per Cl
1.	Grease Pencils Leads, Black	G53-P-28026-600		@ 12
2.	Grease Pencils, Black	G53-P-2864-210		@ 6
3.	Pencils, Lead, Black	G53-P-30004		@ 200
4.	Paper--Ruled Pads	G53-P-1244	Pads	200
5.	Erasers--Chalk Board	G53-E-5380-50		@ 10
6.	Rulers--12 Inch--Desk	53-R-4200		@ 10
7.	Protractors, 6"	GA18-P-24920		@ 200
8.	Compass--Drawing	G18-C-1605		@ 200
9.	Graph Paper, Rectangular Coordinate	G53-P-10135	Sheets	500
10.	Chalk, Red	G53-C-15345-40	Bx	1
11.	Chalk, Blue	53-C-15345-10	Bx	1
12.	Chalk, White	53-C-15345-50	Bx	1
13.	Chalk, Yellow	53-C-15345-60	Bx	1
14.	Chalk, Orange	53-C-15345-30	Bx	1

I. Other Items

Item No.	Description	Per Cl
1.	*78655A Pith Balls, Suspension type, metal coated	2
2.	*78640 Cat Skin, half	5
3.	*78620 Friction red, hard rubber (vulcanite)	5
4.	*78700 Electroscope, pith Ball (Electrical Pendulum)	10
5.	*78288 Magnet, bar alnico 5	2
6.	*78328 Magnet, horseshoe--alnico 5	2
7.	*78395 Iron Filings no. B	6
8.	*79740 Coil for inductance	2
9.	*83916 Cable, flexible stranded	6 yds.
10.	*83900 Connector tip	60
11.	*83800 Binding post	24
12.	;; "CL" push-back wire solid #1466 Q size 20, Alpha Wire Corporation	black 100 ft red 100 ft.
13.	;; Test lead wire, AWG #18 rubber insulation. Trade #8899 Beldon Radio Co.	black 100 ft red 100 ft.
14.	;;5305-45 Volt "B" battery	4
15.	Silica Gel--Indicating	lbs. 5
16.	--Device No. 28-A-7, Optical Pointer	2
17.	--Device No. 30-A-6, Battle Phone Talker Recording	2

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